TECHNOLOGY QUARTERLY.

PUBLISHED BY THE STUDENTS OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

VOL. I. FEBRUARY, 1888. No. 3.

METHODS OF INSTRUCTION IN MINERALOGY AND STRUCTURAL GEOLOGY, IN THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

BY W. O. CROSBY, S.B., ASSISTANT PROFESSOR MINERALOGY AND LITHOLOGY.

Read before the American Society of Naturalists, at New Haven, Dec. 29, 1887.

THE subjoined note * shows that, while those Institute students who desire to give special attention to geological studies are accorded ample opportunities to do so, the crowded curricula of the professional courses allow rather scant time for the regular class instruction in this department.

The problem presented to the instructors of combining in these time-limits such a comprehensive and thorough survey of the subject-matter of these sciences as the practical nature of the Institute courses demands, and the training in personal observation, in the inde-

*The following statement of the instruction in the Geological sciences given at the Institute of Technology, is introduced here especially to indicate more clearly the courses in which the methods explained in the following pages have been most thoroughly tested; viz., Mineralogy and Structural Geology. The title of the paper is not intended to convey the impression that these methods are inapplicable to the important division of Historical Geology; but their full adoption here has been retarded mainly by the greater difficulty and expense of obtaining suitable material.

The Geological sciences are taught in the order of their logical succession; hence the work done in one course is a preparation for the next. The regular instruction in Mineralogy is given in the second half of the second year, to all students in Mining Engineering, Chemistry, and Natural History (excepting those who are preparing for the Study of Medicine), and to all students taking the geological options in Civil Engineering and General Studies. The time allowance is 60 hours for Descriptive Mineralogy, with 30 additional hours for preparation, and 30 hours for Determinative Mineralogy. Dynamical Geology is also taught, in connection with Physical Geography, in the second half of the second year. It is taken by all students in Civil Engineering, Natural History, and General Studies; and by the geological options in

pendent acquisition of knowledge or real learning, required by the modern and progressive ideas in science-teaching, has been, it is believed, solved in a large measure by the gradual evolution during the past decade of the system of instruction outlined in the following pages. The most prominent and essential feature of this system is the liberal use of specimens. Collections take the place of books in an unusual degree; and oral instruction and laboratory work are combined in nearly every exercise. Only the work of the regular classes in these subjects will be noticed here, since advanced and special students, being less restricted as to time, offer a less difficult problem to the instructors.

It must be confessed at the outset that the environment of the Institute is exceptionally favorable to the adoption of rational methods in geologic instruction. The immediate vicinity of Boston, or the district known by local geologists as the Boston Basin, is not only an excellent field for the study of lithological and structural geology, but what the local geology lacks is largely supplied by the extensive and valuable collections of the Boston Society of Natural History. These are very conveniently placed, are accessible to students at all times, and have been arranged with special reference to their needs; while the Mineralogical guide, published by the Society, is essentially a text-book illustrated by the collections, and proves a very valuable adjunct in instruction. The absence, however, of these or similar external aids must, obviously, increase, rather than diminish, the importance of the

Mining Engineering and Chemistry. The time covered by this course is 45 hours for lectures, and 45 hours for preparation.

Structural Geology, including Lithology, is given in the first half of the third year to all students in Civil and Mining Engineering, Architecture, Natural History, and General Studies, and to the geological option in Chemistry. This course is allowed 30 hours for lectures and laboratory work, 30 hours for preparation, and about 10 hours for field lessons. Fifteen lectures on Chemical Geology, with an equivalent time for preparation, are also given in this term to all students in Mining Engineering and Natural History (except those preparing for the Study of Medicine), and to the geological options in Civil Engineering and Chemistry.

Historical Geology is taught in the second half of the third year to all students in Civil Engineering, Mining Engineering, Natural History, and General Studies, and the geological option in Chemistry. The time for this course is 45 hours for lectures, and 45 hours for preparation.

Instruction in Advanced or Special Geology, amounting to about 400 hours in the third year, and 750 hours in the fourth year, and varied to meet the needs of individual students, is given to students in Natural History who desire a special training in Geology rather than Biology. Similar advanced work and field work in Geological subjects is included in the geological options in Civil Engineering and Mining Engineering for the fourth year.

free use of specimens, and the adoption of the best methods generally in the class-room.

The liberal use of specimens in science-teaching is a principle that is generally conceded. But too many teachers interpret this to mean simply that there should be in the possession of the school, usually under lock and key, out of reach, if not out of sight of the students, a collection consisting of one specimen each of as many different types as possible, the rarer and more unique varieties often occupying the most prominent place.

Unquestionably, it is desirable that every school should possess such a reference collection of carefully selected typical specimens, and that they should be so arranged that they can be readily examined in a good light. The place of such a collection at the Institute of Technology is taken mainly by the collections of the Boston Society of Natural History. But no single specimen or reference collection can properly be made the principal basis of systematic instruction, except with very small classes.

The best that can be done with such a collection is, at each lesson, to place the specimens relating to it on the teacher's desk. But, while the teacher has thus a good opportunity to become familiar with the properties of typical specimens, so far as the students are concerned the specimens might almost as well have been left in the cabinet. And the result is not appreciably more satisfactory if each specimen is, in turn, passed around the class. For then the work must either lag, and the time of the class be largely wasted; or, what is worse, the individual student will frequently be observing a specimen of one type while the teacher is explaining another type.

In the Geological Department of the Institute, and in the Laboratory of the Boston Society of Natural History, the liberal use of specimens means, among other things, and chiefly, having, so far as practicable, a good specimen of every important type for each student, or at least for every two or three students. In other words, it means placing before each member of the class, as well as before the teacher, a complete or nearly complete series of the specimens required, not so much to illustrate the lesson, as to form the material basis of study, the principal subject-matter of the lesson itself. The class-rooms are provided with small tables, accommodating from two to four students each; and the specimens are usually placed before the students in light wooden trays, measuring fourteen by eighteen inches and two inches deep. The class-room for Mineralogy and Structural Geology will accommodate in this way thirty-six students. When the class is larger it is divided into two

sections, and the lessons are repeated. The aim is, therefore, to include in the regular teaching collection thirty-six typical specimens of every type or variety taught. These specimens, when not in use, are stored in drawers, a separate drawer being usually allotted to each kind or variety.

Considerable labor is necessarily involved in distributing and collecting the specimens for each lesson; and it has been found that this can be properly performed only by the instructor or an intelligent and trained assistant. Hence this cannot be particularly recommended as an easy method of instruction. Neither is it the cheapest method, since the acquisition, preparation, and storage of the material is expensive as well as laborious. Teachers who have not had the experience are very likely, however, to overestimate this difficulty; for such a teaching collection is not necessarily formed all at once. It is evident, also, that the most important natural types are usually the commonest and most easily obtained, especially when we reflect that the local natural history, the geology of our own neighborhood or country for instance, should always be the teacher's main reliance. It may also be noted in this connection, that in most cases comparatively small specimens will not only answer, but are better than larger ones, and that they need not be selected or trimmed with the same care that would be required for cabinet specimens. From two to three inches square for rocks, and one to two inches square for minerals, are good average sizes for class specimens. The one essential is that the specimens should be fresh and typical.

Although I should be the last one to absolve the authorities of the school from the obligation to provide the proper equipment for the instruction in natural history, as well as in the other departments, still it may be fairly said in most cases that, at least after suitable storage for specimens has been provided, the result depends largely upon the teacher. The immensely greater satisfaction of teaching in the right way instead of the wrong way, ought usually to be a sufficient inducement to improve the opportunities which come to nearly all teachers to obtain suitable material by collection and exchange. The various collections used immediately in the class instruction in Mineralogy and Structural Geology in the Institute, aggregating about eighteen thousand specimens, have been formed almost wholly in this way. Even under the most favorable conditions, nothing can take the place of the vigilant interest of the teacher, since good working collections are necessarily slow growths, and can only be maintained by the constant replacement of old and worn material by fresh.

Through the efforts, chiefly, of Prof. Alpheus Hyatt and the late Miss Lucretia Crocker, this method of teaching natural science has been very

generally adopted in the public schools of Boston, where it was necessary to provide sixty specimens of each kind; and we have the satisfaction of knowing that it is gradually making its way in other parts of the country.

The following statement of the application of this principle to the geologic instruction in the Institute is not presented with the idea that the system which has been evolved is either original or perfect, but simply because its practicability and value have been thoroughly demonstrated. It is also believed that the principal features, at least, are adapted to a wide range of instruction, and hoped that there are many teachers who will not be deterred by considerations of labor or expense from adopting them.

MINERALOGY.

Crystallography is taught with the aid of nearly four hundred wooden and glass models, a large series of natural crystals for comparison with the models and to illustrate the various imperfections of crystals and habits of crystallization, and a large number of charts explaining more clearly the growth and irregularities of crystals as well as the mutual relations and derivation of the crystalline forms. At nearly every lesson in this subject, from five to ten models of the principal forms or combinations already studied are placed before each student for identification and description; and such further explanations as seem to be required are then given by the instructor.

The cleavage and physical properties of minerals are taught with a complete series of illustrative specimens before each student. The various properties of many other specimens are subsequently determined by the class; and the determinations are commented upon and corrected by the instructor while the test specimens are still before the class. Throughout the entire course, especial stress is laid upon the careful and accurate observation and description of minerals.

The instruction in Descriptive Mineralogy is given with the aid of the collections and guide of the Boston Society of Natural History, and the following collections in the Geological Department of the Institute: (1) The regular teaching collection, which occupies a case of one hundred drawers, and includes, so far as practicable, thirty-six typical, unlabeled specimens of every important variety taught; *i. e.*, a sufficient number to supply a class of the maximum size. In the case of the rarer and more expensive minerals, however, it is considered sufficient to have only one specimen for each table. This collection includes two hundred varieties

and about seven thousand specimens. (2) A shelf or display collection of about one thousand specimens, which can be seen but not handled by students, and which are used at the lessons to illustrate the rarer and more perfect forms of each species. (3) The students' collection, which is kept in conveniently placed drawers in the class-room, and consists of about five hundred carefully labeled specimens, including a single typical example of nearly every variety which is referred to in the instruction. This collection is accessible to students at all times; and they are allowed to handle and test the specimens freely in a good light. Its use insures a much more thorough, practical acquaintance with the properties of minerals than would otherwise be possible, and amply repays the trifling labor and expense required to keep the collection in order, and replace the worn or broken specimens. These collections are supplemented by a large series of outline drawings illustrating the crystallization of every important species.

At the regular lessons in Descriptive Mineralogy, each student is provided with a tray containing as complete a series as practicable of illustrative specimens, and with facilities in the form of a lens, file, magnet, acid, etc., for properly observing and testing them. So far as the time will permit, the work with every well-characterized specimen, or group of specimens, in case several varieties of the same species are represented, begins by each student writing out a careful description of it on a blank supplied for the purpose. Only the name and composition of the specimen are supplied by the instructor at first; and the class determine by actual examination the form, cleavage, hardness, specific gravity, lustre, color, streak, diaphaneity, tenacity, etc.; and in many cases, also, they are required to state what chemical behavior is indicated by the composition given. The student's best efforts in all such work are insured by the fact that his descriptions are marked, and form an important part of his record in the subject. But he learns at once, from the systematic account of the species by the instructor which follows, to what extent his description is faulty, and which are the constant or important and the variable characteristics. Especial stress is laid here upon the properties useful in identification.

The lessons usually begin with a brief examination or test. The first row of specimens in each tray is made up of five to ten examples of the more important minerals of the preceding lessons, and the students are required to write out the name and composition of each of these. A record is kept of these tests, and as soon as the papers are collected the instructor gives the correct answers, and points out again and distinctly the salient features of each species, emphasizing its contrasts

with the species which most closely resemble it. The principal object of these tests is to afford the class as many additional opportunities as possible to observe and handle the leading types of minerals, since this is essential to the practical familiarity with the concrete aspect of the science which is rightly assigned a prominent place in technical education. The extended review of Descriptive Mineralogy, closing the work of the term, contributes in a marked degree to the same result. The main course is based upon the scientific classification of Dana's System and Text-book, while the review is based upon the economic classification of Dana's Manual of Mineralogy.

The work in Determinative Mineralogy need not be noticed here further than to state the writer's conviction that, since in the actual practice of after life mineral determinations are, and must be, based chiefly upon the physical characters, this method deserves more attention than it usually receives in courses of instruction.

LITHOLOGY.

The regular course of instruction in this branch of geology is wholly macroscopic, only advanced students working with the microscope; and the instruction is conducted along essentially the same lines as that in Mineralogy.

Besides the systematic collection of rocks in the Natural History Museum to which students are referred, and a collection of dressed and polished blocks of typical building-stones in the Geological Department of the Institute, the following collections are used: (1) The regular teaching collection, which occupies two hundred drawers, and includes, so far as practicable, thirty-seven typical, unlabeled specimens of every variety taught. The more important lithologic types, such as sandstone, limestone and granite, are each represented by from five to twenty varieties; and the totals for the entire collection are two hundred varieties, and over seven thousand specimens. (2) The students' collection of rocks, which includes over three hundred typical and carefully labeled specimens. This collection, like the students' collection of minerals, is kept in the class-room, where it can be freely used by students in a good light at all times.

At the lessons in Lithology, as in Descriptive Mineralogy, each student is provided with a complete series of specimens, and in the various ways already explained, the class is given as much practice as possible in the description and determination of the principal types, especial emphasis being laid upon the mineralogical composition and texture.

PETROLOGY.

The application of this principle of multiple specimens to instruction in Petrology, or Structural Geology proper, is much more difficult and less important than in Mineralogy and Lithology. It is more difficult, since, from the nature of the case, the specimens, such as examples of folds, faults, etc., are rarer, and less easily duplicated, except in the case of concretions and some other small types of structure; and it is less important, because the teacher must, in any case, depend largely upon pictures and diagrams, and because such natural illustrations as can be obtained are often large enough so that a single specimen can be clearly seen by a large class. The petrological collection at the Institute embraces nearly a thousand specimens; about two thirds of these being in sets large enough to supply the class.

Field lessons are, however, regarded as of especial value in this branch of geology, and the Institute course is purposely arranged so that this part of the instruction comes during pleasant weather. In no part of his work has the teacher of geology a better opportunity to show his fitness for his task, than when he thus brings his class face to face with the actual problems of geology. What field instruction ought to be, has been, however, so recently and admirably stated by Prof. W. M. Davis, that I need only congratulate teachers on the publication of his paper in the *American Naturalist* for September, where it is accessible to all.

In conclusion, I would state that the statistics of the Institute collections have been introduced here merely as an illustration of the extent to which duplicate material for class instruction may be obtained without any undue effort or expense, if the teacher is simply impressed with the importance of this method, and learns that it is really but little more trouble to have fifty pounds of almost any material he may be collecting sent home by express, than to carry away two or three pounds in his hands.

DISCUSSION OF THE PRECISION OF MEASUREMENTS.

BY SILAS W. HOLMAN, S.B.

(CONTINUED.)

Significant Figures. By a significant figure is meant any digit other than zero. By places of significant figures will be meant places which properly may contain significant figures; *i. e.*, places other than those where zeros are used simply to enable the position of the units place to be indicated, as when zeros are prefixed to significant figures in a decimal fraction, or suffixed to them when significant figures are not

known for all the places down to the units. The decimal point is simply a conventional sign to indicate the units place, and its position in no way indicates or affects the number of significant figures or the fractional accuracy of a result. Thus, for instance, to say that a distance was measured to 0.1 mm. gives no indication of the number of places or the fractional precision, unless we know what the whole distance was. Suppose that this was about 2 metres. Then the fractional precision would be the same; viz., 1 in 20,000, whether written as 2 m., or 20 dm., or 2000. mm., or 0.002 kilom. And in computations involving this distance, six places of significant figures would be retained, independent of what unit it was originally expressed in. Rules for the rejection or retention of places of significant figures in data and computations may be deduced from the principles already presented. They are important for the avoidance, on the one hand, of waste labor and a delusive or ludicrous display of figures, and on the other to insure to the computed result all the accuracy to which it is entitled by the data.

Let M be an original observed quantity and δ its average deviation. Let that place of figures in M which corresponds to the second place of significant figures in δ be called the rth place. The average deviation by its derivation denotes that M is uncertain on the average by an amount δ. For instance, if $\delta = 0.034$, then M on the average is uncertain by 3 units in the $(r-1)$th place; *i. e.*, in the place corresponding to the first significant figure in the average deviation, and in the rth place by 34 units. In general, the first significant figure in the δ may be anything from 1 to 9, as the case may be; hence in general M is uncertain by 1 to 9 units in the $(r-1)$th place, and by 10 to 90 (or strictly 10 to 99) in the rth place. Thus the digit in the $(r-1)$th place in M is always somewhat uncertain, and that in the rth place is very uncertain. It is useless, therefore, to retain significant figures in M beyond the rth place, and when the δ is large even this place is of little use. Also two places of significant figures in any δ are all that are of any use, since the only service of the δ is as an index of the precision of its quantity M,— or stated in another way, because, as may be seen by inspection, the second and subsequent places of significant figure in any δ are very uncertain.

Thus anything which affects a quantity M beyond its rth place is wholly negligible, and in all ordinary work any effect less than 0.1 δ is sufficiently small to be neglected, for M is of itself uncertain on the average by ten times this amount. Let us adopt, then, as the basis of rules for significant figures, the condition that the accumulated error arising from the rejected places of figures must not at any stage of the computation exceed that corresponding to $\frac{1}{10} \cdot \frac{\delta}{M}$ when this has its *mini-*

mum value. This will be quite close enough for all physical work, except possibly of extreme refinement, and will give rules which may be applied to data of seven or less places of figures, and which may be occasionally relaxed, *with judgment*, in ordinary work. Let the rules be framed for giving the number of *places* to be retained, as this gives the greatest convenience in practice. Now the minimum value of $\frac{1}{10} \cdot \frac{\delta}{M}$ would be that where the first two significant figures in δ were respectively 1 and 0, and in M were 9 and 9; *e. g.*, $\delta = 0.010$, $M = 9.999$. For this case $\frac{1}{10} \cdot \frac{\delta}{M}$ would be $\frac{1}{10000}$th, corresponding to unity in the rth place of M. Then the *accumulated computation error at any stage* must not exceed 1 unit in the rth place of figures. The errors introduced by the rejection of figures beyond the rth place, adding one unit to the figure in that place when the first rejected figure is 5 or over, are distributed according to the first special law, p. 129. Thus the average error will be $\frac{1}{4}$ of a unit in the rth place at each rejection. These errors in a process of several additions or subtractions will accumulate as expressed by XIV., and by the special law of error just referred to. By these jointly it appears, then, that the accumulated error will be proportional approximately to $\sqrt{n}$ where n is the number of rejections. In multiplication or division the accumulation will follow the law of XVI. and XVII. At each step and in the final result the effect of each rejection will remain as the same fractional error of the quantity, though changing in its value in units in the rth place, in consequence of previous multiplications, etc. Thus in the final result the rejection errors as units in the rth place will follow the same law of distribution as at the point where they were rejected, and their combined effect may be computed as approximately proportional to $\sqrt{n}$, as for addition or subtraction. All other arithmetical processes may be regarded as combinations or modifications of the four primary ones. Let us then write as the limit $\frac{1}{4}\sqrt{n} < 1$ unit in the rth place, which solved for n gives $n < 16$. If, then, we reject always all places beyond the rth, we shall, on the average, not have in 16 rejections, and hence in any ordinary work, an accumulated computation error beyond the assigned small limit. We have, then, the following rules: —

Rules for Significant Figures:—

1. In the δ (*ad* or *AD*) two places of significant figures should in general be retained, but the first place will sometimes suffice if the digit in that place is large.

2. In a single observation the last place of significant figures retained should be usually the rth place; viz., that corresponding to the second place of significant figures in the *ad* of a series of such observations. It is sometimes sufficient to retain one place less than this when the digit in the first place of the *ad* is large. In other words, retain the place corresponding to the last place properly retained in the *ad* under rule 1.

3. In a mean or average, retain places to include that corresponding to the second place of significant figures of its *AD*. Sometimes one less place than this may suffice. In other words, retain places to correspond to the last place properly retained in the *AD* under rule 1.

4. In addition or subtraction, carry the sum or difference only to that place which corresponds to the second significant figure in the *ad* or *AD* of the *least* precise quantity; *i. e.*, of the one with the largest δ. It will depend on the number and kind of quantities to be added or subtracted whether or not these quantities should each be carried to one place beyond that in which the last figure of the final result is desired, this extra place being rejected in the final result.

5. In multiplication (or division) carry out the product (or quotient) at any stage of the work only to the number of places retained in the original quantity under rule 2 or 3. If several measured quantities are to be multiplied (or divided) into each other, carry the product (or quotient) and the separate factors only to that number of places which would be retained under rule 2 or 3 in the least precise factor. It may sometimes be well to carry known factors, such as π, g, etc., to one place more than this rule would prescribe for the measured factors.

6. In the use of logarithms, the mantissæ should be retained to as many places as there should be places of significant figures retained, under rule 5, in the number corresponding, if the multiplication or division were to be performed directly. The characteristic is not to be considered, as it serves merely to locate the decimal point.

Closeness of Corrections, Constants, etc. Let M_1 be the mean of a series of observations, and δ_1 be its precision measure as computed from these. Let c be a correction to be added to M_1, and determined by comparison with standard, or in any way whatever, with a computed or estimated precision measure δ_c. Then δ, the precision measure of the corrected mean $M_1 + c$, will, by XIV., be found from $\delta^2 = \delta_1^2 + \delta_c^2$. Now, by the statements of p. 195, it is obvious that anything producing on M_1 an effect less than about $0.1\delta_1$ may be consid-

ered as insensible or negligible. Keeping this in view we may obviously have the following cases:—

1. If $c < 0.1\delta_1$ the correction may be omitted.

2. If c is of same order of magnitude as δ_1 it may be neglected only in coarse work, and should be then taken into account in making up δ. As c, in any case, is of constant sign, this omission is not admissible in fine work.

3. Whatever the value of c, if $\delta_c < 0.1\delta_1$, then $\delta = \delta_1$ sensibly; so that c may be regarded as exact, and δ_c neglected.

4. Whatever the value of c, if $\delta_c > 0.1\delta$, then δ_c must be taken into account in making up δ.

Inspection will show that for constants, or other terms added to or multiplied into any quantity, such as M_1 above, the effect on M_1 of rejection of superfluous places of figures, or of errors or deviations in these quantities, may similarly be neglected when less than $0.1\delta_1$. Of course in very exact work this margin may be narrowed somewhat; in coarse work it may be broadened.

Estimated Precision Measures. Circumstances sometimes render it difficult or impossible to obtain the precision measure by direct observation. But in such cases it is often possible to obtain an approximate or estimated δ. A simple estimation of the ad may be the best thing available. But usually it is easier to estimate what would be the extreme deviation which might occur in, say, 1,000 readings. Let h denote such an extreme deviation. Now, the general law of distribution shows that the deviation whose frequency is 1 in 1,000 has, in the long run, about four times the magnitude of the average deviation; *i. e.*, $h = 4\,ad$, whence an approximate ad may be computed from an estimated h. This relation between h and ad is often of service in other ways, as for instance where an extreme variation of some kind can readily be observed, but the average cannot.

Example. The following illustrates the application of the foregoing methods: Required the work W done in one stroke by an engine piston of diameter d and stroke s, working at a mean indicated pressure of intensity p as found from an indicator card. $W = \frac{1}{4}\pi d^2 ps$.

There may be two cases: one in which the data are already determined, and the quality of the result is under scrutiny; the other in which (as should always be done when possible) it is desired to determine in advance of the work what the precision should be in the components

1. Having given the data and their precision measures, to find what reliance may be placed upon the result. In order to estimate the accu-

racy of the result, it is essential to inquire first into the accuracy with which the instruments were known, and whether they were properly applied in the measurements. Unless we can obtain suitable information on these points, which properly should go with the original statement of the result, it is impossible to discuss the quality of the result. Suppose, then, that it were further stated that the micrometric apparatus used in measuring the diameter and length of stroke had been tested under proper conditions, and corrections had been determined which brought its indications to agreement with the standard with an *ad* of 0.00030 inch; also that the indicator spring had been checked against a mercury column, and the correction determined to an *AD* of 0.06 lbs.; also that due care as to temperature effects and all other discoverable sources of error was exercised when the measurements were made, so that it was deemed that no determinate source of error beyond the suitable limits was overlooked.

The data are:—

$d = 10.020$ in. $\quad ad = 0.010$ in. $\quad n = 25.$ $\quad \therefore AD = 0.0020$ in.

$p = 20.00$ lbs. $\quad ad = 0.6$ lbs. $\quad n = 10.$ $\quad \therefore AD = 0.20$ lbs.

$s = 15.04$ in. $\quad ad = 0.0040$ in. $\quad n = 1.$

whence $W = 23720.$ inch-lbs.

We have now to find from the observed deviations their combined effect on the result. This is most readily done by separating into the factors $\frac{1}{4} \times \pi \times d^2 \times p \times s$. Of these, $\frac{1}{4}$ is an exact number; and π is a numerical constant known with indefinitely great closeness; so that both of these may be considered by themselves later, and carried to so many places as not sensibly to vitiate the result. Then by XX.

$$\left(\frac{\Delta W}{W}\right)^2 = \left(\frac{\delta d^2}{d^2}\right)^2 + \left(\frac{\delta p}{p}\right)^2 + \left(\frac{\delta s}{s}\right)^2$$

From XVIII we have $\frac{\delta d^2}{d^2} = \frac{2\delta d}{d}$. Note that we cannot separate into the factors $\frac{1}{4} \times \pi \times d \times d \times p \times s$, because the third and fourth would then *not* be independent. Substituting, then, the numerical values $\delta d = 0.0020$ in., $\delta p = 0.20$ lbs., $\delta s = 0.0040$ in., we have

$$\left(\frac{\Delta W}{W}\right)^2 = \left(2.\frac{0.0020}{10.}\right)^2 + \left(\frac{0.20}{20.}\right)^2 + \left(\frac{0.0040}{15.}\right)^2$$

$$= 0.00\ 000\ 016 + 0.00\ 010 + 0.00\ 000\ 007 = 0.00\ 010$$

$$\therefore \frac{\Delta W}{W} = 0.010 \text{ or } 1 \text{ per cent, and } \Delta W = 0.010 \times 23720. = 240$$

in.-lbs.

The number of places to be retained in π is such that the error introduced by the rejected places will not exceed 0.1 to 0.01 of the effect of the δ of the least precise factor in the data, viz., p. Now $\frac{\delta p}{p} = 0.010$. As π is a factor we have, then, $\frac{\delta \pi}{\pi} < 0.1 \times 0.010 < 0.0010$, whence $\delta\pi < 0.0010\ \pi < 0.0031$. Hence $\pi = 3.142$ will be exact enough. A better illustration of this point occurs in the second part of this example.

From this result for ΔW we know that the ad of W is 240 inch-lbs., and that $\frac{ad}{W} = 0.01$, or 1 per cent. And as it has been shown that due regard has been paid to keeping the determinate errors suitably below the deviations, we are justified in using this value of ΔW as our estimate of the reliability of the result, as it is the best estimate which we can form. That is, other measurements made with a corresponding grade of care, but with wholly different instruments, would *probably* give results agreeing with this *on the average* to about one per cent. Unsuspected errors may, of course, exist, and of a nature not to be eliminited by averaging — whence the word "*probably*." For instance, it might have occurred that the indicator spring had received an unsuspected injury subsequent to test.

From the numerical values in the above expression for $\left(\frac{\Delta W}{W}\right)^2$, it will be seen at a glance that the precision in p is much too small as compared to that in d and s. Hence much of the labor spent in measuring the latter was thrown away. This might have been prevented, and the needful care might have been determined beforehand by the solution to be now given.

2. Required to determine in advance of the measurements, and from rough values, the necessary precision in the various components. The problem would be stated thus:—

Desired the work, W, done upon the piston of a steam-engine in a single stroke under the indicated pressure p of about 20 lbs., the stroke s being about 15 inches, and the diameter d about 10 inches. Accuracy wished for in W is 1 in 1000., or 0.1 per cent. How closely must the values of d, s, and p be measured, and how far should π be carried out?

Separate into factors the expression for W, as before, and lay aside the constants $\frac{1}{4}$ and π. Then imposing the condition of equal effects of the δ's upon the result, we have

$$2\frac{\delta d}{d} = \frac{\delta p}{p} = \frac{\delta s}{s} = \frac{1}{\sqrt{3}} \cdot \frac{\Delta W}{W} = \frac{1}{\sqrt{3}} \times 0.001 = 0.00058$$

$$\therefore\ \delta d = \tfrac{1}{2} \times 0.00058 \times 10. = 0.003 \text{ inch.}$$
$$\therefore\ \delta p = 0.00058 \times 20. = 0.012 \text{ lbs.}$$
$$\therefore\ \delta s = 0.00058 \times 15. = 0.009 \text{ inch.}$$

For the constant π we should have the requirement that $\frac{\delta\pi}{\pi} < 0.01 \times 0.00058 < 0.00006$ $\therefore\ \delta\pi = 0.00006 \times 3.1 = 0.00019$; whence $\pi = 3.1416$ would amply suffice.

It thus appears that for the assigned limit of accuracy $\frac{\Delta W}{W} = 0.001$, we must have the average deviations of d, p, and s respectively not over 0.003 in., 0.012 lbs., 0.009 in.; and all determinate errors must have been so far removed from the work, by corrections and otherwise, that their residuals may safely be classed among the indeterminate errors. These δ's must include the average deviations not only of the direct measurements in each case, but those of the corrections used also, as stated in the paragraph on closeness of corrections.

Best Magnitudes. In using almost any instrument it will be found that, on account of the nature of its indications, its greatest accuracy is secured at a certain point or within a limited part of its range. In designing an instrument there will be a best proportion among its parts. In arranging the plan of an indirect measurement, there will be some magnitudes more favorable than others to be assigned to the various component measurements. Thus in general there will be best magnitudes, either actual or relative, of the components. For instance, current measurement by a tangent galvanometer, whose readings are taken from a circular scale of equal parts, is fractionally more precise at or about 45°; — a bar whose moment of inertia, I, is to be computed from its dimensions and weight, may have for a given value of I a best proportion between its length and diameter; — in the magnetometer there is a best ratio between the distances from the needle to the two positions of the deflecting magnet.

The problem therefore arises to determine what these best magnitudes are in any given case. This is but another and higher phase of the subject already presented. Instead of determining, as by "equal effects," the best values of the precision measures for given magnitudes of the components, we are now to determine the best magnitude of the component quantities for prescribed conditions in regard to the precision in their measurement, and to the relative or absolute magnitudes of the final result or one or more of the components.

These conditions are thus of two sorts, viz.: First, ***Precision Conditions;*** *i. e.*, having given the absolute or relative precision

measures δ_1, δ_2, etc. Second, ***Magnitude Conditions;*** *i. e.*, having given the absolute values of the final quantity, M, or the absolute or relative values of the components M_1, M_2, etc., or of the final quantity and one or more of the components. To see more closely what this statement implies, consider that throughout all this subject, where we deal with the effect of errors of measurement, those quantities or components are treated as independent which are the subject of separate or independent measurement — not calculated from another. But quantities may properly be thus independently measured and treated which are not mathematically independent, but are "conditioned," so that one is capable of expression in terms of another either with or without another independent quantity. The function expressing such a relation would then give an equation of condition which must be regarded in determining the "best magnitudes," though not needed in the simpler case of computing the precision of the result, or assigning the precision of components.

As Examples of Conditions let us take the following:—

a. Required the best values of c, r, and t for measuring the electric energy, $W = c^2rt$, expended in heating a conductor. Given as *precision conditions* $\delta c = 0.01$ ampere, $\delta r = 0.01$ ohm, $\delta t = 0.2$ sec.; *magnitude condition* $W = 5\,000\,000.$ units. Note that the quantities c, r, and t, are wholly independent except for the magnitude condition that W is fixed. The numerical solution is given at p. 204.

b. It is desired to construct to best advantage a right circular cylinder of brass, whose moment of inertia around a transverse central diameter is to be computed from $I = m\left(\frac{h^2}{12} + \frac{d^2}{16}\right)$ where $m =$ mass, $h =$ height or length of cylinder, $d =$ diameter of cylinder. The value of I is most easily determined by measuring directly m (by the balance), h and d, which would be treated as independent (independently observed) if we were discussing the precision of I. Now, in determining the best magnitudes of m, h, and d we must know first the precision conditions. Suppose the measurements show these to be, $-\delta m$ negligible, $\delta h = \delta d =$ constant. Second, we must have the magnitude conditions,— which would vary with circumstances. Suppose that it is required that I shall be of a given amount. Then as δm is negligible, m may have any value consistent with the other requirements, and we have to find the best value of the ratio of h to d. But h, d, and m, although independently observed, are not mathematically independent; for $m = \frac{\rho\pi d^2 h}{4}$ where ρ is the density of the brass. Hence

the magnitude conditions are $I =$ constant, and $m = \frac{\rho \pi d^2 h}{4}$. The algebraic solution is given at p. 206.

Methods of Solution of problems on best magnitudes may be reached in two principal ways. First, whatever the number of the components, provided that they are mathematically, as well as by observation, independent, we may show from the principle of least squares, as in deducing the formula XXI for "equal effects," that in the long run the best magnitudes of these components will be found by solving for them from either the general expression XXI or the proper special one from XXII to XXV. The solution will, of course, be made for values either absolute or relative of the components M_1, M_2, etc., under both the assigned precision conditions respecting δ_1, δ_2, etc., and the magnitude conditions. The method is intended for those cases involving three or more variables, and which cannot well be solved by the second method, about to be described. Its results are but approximate, and therefore will differ usually by a slight amount from those obtained by the second method, which is to be preferred for one or two variables. But it is to be remembered that a considerable departure from the best conditions will affect the precision but slightly, and that best values to 10 per cent are usually more than sufficiently close.

Second, if the number of components is one or two, and if two, whether independent of each other or one a function of the other, we may solve more exactly by the usual process of finding minima by differentiation. (Todhunter's Differential Calculus, chapter on Maxima and Minima of Two Variables.) By this process the general plan of the solution would be this: Write by means of formulæ XIII to XX the expression for Δ or Δ^2 in terms of the δ's as given by the precision conditions. Simplify as much as possible, and find by differentiation the values of M_1, M_2, etc., which will make Δ a minimum.

The cases which arise in differentiating are as follows:—

1. Where $u = f(x)$, *i. e.*, where it is required to find the value of x which will make u a minimum, u being a function of x alone. Here, of course, the desired value of x will be formed from the familiar conditions.

$$\frac{du}{dx} = 0, \text{ and } \frac{d^2u}{dx^2} \text{ is } +. \qquad \text{XXIX.}$$

Inspection alone often suffices to solve this simple case.

2. Where $u = f(x, y)$, but x and y are *not* independent, but $y = \psi(x)$. In this, the most common case, the general solution is by the equation.

$$\left(\frac{du}{dx}\right) + \left(\frac{du}{dy}\right).\psi'(x) = 0, \qquad \text{XXX.}$$

where the parentheses indicate that the differentiation with respect to the variable is made on the supposition that the other at the time remains constant; and where $\psi'(x)$ denotes $\frac{d\psi(x)}{dx}$. Of course there are further conditions to discriminate between maxima and minima, etc., which must be applied when inspection alone does not suffice. The expression XXX is solved for the best values of x, or of $x : y$, or of x and y, etc., as the case in hand may require.

It is often convenient, instead of employing XXX, to substitute directly for y its value $\psi(x)$, so that $u = f(x, \psi(x))$, and then to differentiate with respect to x and equate to zero, as in XXIX.

3. Where $u = f(x, y)$ but x and y *are* independent. In this case both conditions

$$\left(\frac{du}{dx}\right) = 0, \text{ and } \left(\frac{du}{dy}\right) = 0 \qquad \text{XXXI.}$$

must be fulfilled. The parentheses indicate as in XXX. As before, the further conditions for minima have seldom to be considered, as inspection serves to discriminate in most cases.

Solution of Examples of Best Magnitudes.

1. Problem stated at *a*, p. 202. $W = c^2 r t = 5\,000\,000$. Precision conditions: $\delta c = 0.01$ ampere, $\delta r = 0.01$ ohm, $\delta t = 0.2$ second. Magnitude condition: $W = 5\,000\,000$.

To find magnitudes of c, r, and t to make ΔW a minimum. Solving by equal effects (general expression XXI.)

$$\frac{dW}{dc}.\delta c = \frac{dW}{dr}.\delta r = \frac{dW}{dt}.\delta t$$

$$\frac{dW}{dc} = 2crt, \qquad \frac{dW}{dr} = c^2 t, \qquad \frac{dW}{dt} = c^2 r.$$

$$\therefore\ 2crt \times 0.01 = c^2 t \times 0.01 = c^2 r \times 0.2$$

$$\therefore\ r = \frac{c}{2} \text{ and } t = 10c$$

Substituting these gives

$$W = 5\,000\,000. = c^2 \times \frac{c}{2} \times 10c = 5c^4$$

$\therefore\ c = 32$ amperes, $r = 16$ ohms, and $t = 320$ seconds are the desired best magnitudes.

Or by the formulæ for factors (XXIV),

$$\left(\frac{\delta c^2}{c^2}=\frac{2\,\delta c}{c}\right)=\frac{\delta r}{r}=\frac{\delta t}{t} \quad \therefore \frac{2\times 0.01}{c}=\frac{0.01}{r}=\frac{0.2}{t},$$

$$\therefore r=\frac{c}{2}, \text{ and } t=10c. \quad \therefore W=5\,000\,000=c^2\times\frac{c}{2}\times 10c=5c^4$$

$\therefore c=32$ amperes, $r=16$ ohms, $t=320$ seconds, as before.

2. Suppose a tangent galvanometer read by an index moving over a circle graduated to equal parts. The precision measure, $\delta\varphi$, of deflection readings will be the same at all parts of the scale. Let φ be any reading, and K the galvanometer factor, the current is given by $C=K\tan\varphi$. Required the value of φ at which the errors of reading will have least effect, *i. e.*, for which $\frac{\Delta C}{C}$ will be a minimum.

Precision condition: $\delta\varphi=$ constant.
Magnitude condition: none.
By XV.

$$\Delta C=K\,\frac{d\tan\varphi}{d\varphi}=K\sec^2\varphi, \quad \therefore \frac{\Delta C}{C}=\frac{1}{\sin 2\varphi} \qquad \text{XXXII.}$$

By XXIX the value of φ, which will make $\frac{\Delta C}{C}$ a minimum, is to be obtained from

$$\frac{d}{d\varphi}\left(\frac{\Delta C}{C}\right)=0. \quad \text{But } \frac{d}{d\varphi}\left(\frac{\Delta C}{C}\right)=\frac{d}{d\varphi}\left(\frac{1}{\sin 2\varphi}\right)=\frac{d}{d\varphi}\left(\operatorname{cosec} 2\varphi\right)=-\frac{\cos 2\varphi}{\sin^2 2\varphi}$$

Hence $-\frac{\cos 2\varphi}{\sin^2 2\varphi}=0, \quad \therefore -\cos 2\varphi=0,$ and $\varphi=45°$, as, indeed, might have been seen at once from inspection of XXXII.

3. It is desired to construct a circular brass cylinder of given mass, m, whose moment of inertia around a central transverse diameter may be determined by measurements of its mass and dimensions with as great accuracy in units as possible. $I=m\left(\frac{h^2}{12}+\frac{d^2}{16}\right)$, where $h=$ height or length and $d=$ diameter.

Precision conditions: δm negligible, $\delta h=\delta d=$ constant. Magnitude conditions: $m=$ constant, and $m=\frac{\rho\pi d^2 h}{4}$ where $\rho=$ density of brass $=$ a constant.

From XIII. we find

$$\Delta^2 I=\frac{m^2 h^2}{36}\cdot\delta^2 h+\frac{m^2 d^2}{64}\cdot\delta^2 d \text{ or as } \delta h=\delta d$$

$$\Delta^2 I=\frac{m^2}{4}\left(\frac{h^2}{9}+\frac{d^2}{16}\right)\cdot\delta^2 h$$

We have now to find the value of $\frac{h}{d}$, which will make ΔI a minimum. Now ΔI is a minimum when $\Delta^2 I$ is so, and therefore (rejecting constant factors) when $\frac{h^2}{9}+\frac{d^2}{16}$ is so. Now h and d are not mathematically independent, because m is fixed, but from above value of m, $d^2=\frac{4m}{\rho\pi h}$.

The case, therefore, falls under XXX, and we have

$$u=\frac{h^2}{9}+\frac{d^2}{16},\quad x=h,\quad y=d,\quad y=\psi(x)=\sqrt{\frac{4m}{\rho\pi h}}$$

$$\left(\frac{du}{dx}\right)=\frac{2h}{9},\quad \left(\frac{du}{dy}\right)=\frac{d}{8},\quad \psi'(x)=-\frac{d}{2h}$$

$$\therefore\ \frac{2h}{9}-\frac{d^2}{16h}=0\quad \therefore\ \frac{h^2}{d^2}=\frac{9}{32},\ \text{and}\ \frac{h}{d}=\pm 0.53$$

Or we may solve by the second way suggested at p. 204, as follows:

$$d^2=\frac{4m}{\rho\pi h}\quad \therefore \text{ substituting this in } \frac{h^2}{9}+\frac{d^2}{16} \text{ we have}$$

$\frac{h^2}{9}+\frac{4m}{16\rho\pi h}$ to be made a minimum. Solving by XXIX.

$$\frac{d}{dh}\left(\frac{h^2}{9}+\frac{4m}{16\rho\pi h}\right)=\frac{2h}{9}-\frac{4m}{16\rho\pi h^2}=0$$

Restoring now for $\frac{4m}{\rho\pi h}$ its equivalent d^2, we have $\frac{2h}{9}-\frac{d^2}{16h}=0$, whence as before $\frac{h}{d}=\pm 0.53$.

4. Problem stated at *b*, p. 202.

Precision conditions: δm negligible, $\delta h=\delta d=$ constant.

Magnitude conditions: $I=$ constant, $m=\frac{\rho\pi d^2 h}{4}$, $\rho=$ constant.

The problem is similar to 3, but the value of I is now determined in advance instead of m, and it is desired to construct the bar so that I may be found with as great fractional accuracy as possible, which as I is fixed will be when ΔI is a minimum. We will solve first by finding the minimum by differentiation.

The value of $\Delta^2 I$ is as in 3, but m is now not fixed, so that h and d are independent of each other. We have not to adjust the magnitude of m, because whatever this may come out, δm is negligible. But m is a function of h and d and ρ, and as it is not constant we must substitute for it the value $\frac{\rho\pi d^2 h}{4}$ before differentiating with respect to h and d, in order

to fulfill the magnitude condition respecting I and ρ. We have now to find the value of $\frac{h}{d}$, which will make ΔI, and hence $\Delta^2 I$, a minimum. Hence, substituting for m and removing constant factors $\frac{d^4h^4}{9} + \frac{d^6h^2}{16}$ must be a minimum.

This case, as h and d are independent, falls under XXXI, and

$$\frac{du}{dh} = \frac{4d^4h^3}{9} + \frac{d^6h}{8} = 0, \quad \text{and} \quad \frac{du}{dd} = \frac{4d^3h^4}{9} + \frac{3d^5h^2}{8} = 0.$$

Equating these, dividing by d^7 and transposing, gives

$$\frac{h^3}{d^3} - \frac{h^2}{d^2} + \frac{27}{32} \cdot \frac{h}{d} - \frac{9}{32} = 0$$

This by approximate solution yields $\frac{h}{d} = 0.47$ as the desired ratio.

[Methods for approximate solution of such equations may be found in some works on algebra; *e. g.*, Wells' University Algebra, p. 417.]

This 4th problem may also be solved, of course, by the condition of equal effects, but, as already stated, the result may not be precisely the same as the more exact one just obtained.

$$I = m\left(\frac{h^2}{12} + \frac{d^2}{16}\right) = \frac{\rho\pi d^2h^3}{48} + \frac{\rho\pi d^4h}{64}$$

As δm is negligible and ρ is constant,

$$\frac{dI}{dh} \cdot \delta h = \frac{dI}{dd} \cdot \delta d, \quad \text{and as } \delta h = \delta d, \quad \frac{dI}{dh} = \frac{dI}{dd}.$$

$$\frac{dI}{dh} = \frac{\rho\pi d^2h^2}{16} + \frac{\rho\pi d^4}{64}, \text{ and } \frac{dI}{dd} = \frac{\rho\pi dh^3}{24} + \frac{\rho\pi d^3h}{16}$$

Equating and transposing gives

$$\frac{h^3}{d^3} - \frac{3}{2}\frac{h^2}{d^2} + \frac{3}{2}\frac{h}{d} - \frac{3}{8} = 0$$

This, by approximate solution, yields $\frac{h}{d} = \frac{1}{3}$ approx. as the desired ratio. This solution by equal effects is not intended, as has elsewhere been stated, for application where the ordinary differentiation will apply, but for cases with three or more variables.

(To be concluded.)

BUILDING LAWS AND THEIR ENFORCEMENT.

BY T. M. CLARK, A.B.

II.

THE Metropolitan Building Act of London, the growth of a long series of enactments and amendments, commonly, perhaps, suggested by particular circumstances, like the modern laws in regard to theatre construction, which are remodeled after every fatal fire in a theatre, has served as the pattern for nearly all the building laws of English-speaking communities. On the whole, this has been rather a misfortune for those communities, since the act, like other legislation built up by an aggregation of enactments made to meet special cases, is cumbrous, uncertain of interpretation, and incapable of adaptation to new materials and methods; and in these respects its more recent imitations closely resemble it. To illustrate the growth of such laws, and show the difference between them and statutes, such as the future may perhaps have in store for us, founded on general principles of construction, one or two examples out of many may be given from American regulations. Here, as in London, an inordinately large portion of the laws as enacted is given to prescribing the thickness of walls. Brick is with us, as in England, the ordinary building material, and the rules for the thickness of walls are the product of many successive experiments. A man once undertook in London to build a row of houses with brick party walls four and one-half inches thick. He actually succeeded in carrying them to a height of thirty feet from the ground, and putting on three tiers of floor-beams, before they collapsed, and fell in a heap into the cellar. Evidently a law-maker, if this were the first instance of the kind, would infer from this that four and one-half inches was too thin for a party wall thirty feet high, and would hasten to amend the building act by prescribing a minimum thickness of nine inches, or one brick, for such walls; and this is practically what was done. Later, however, a nine-inch wall, five or six stories high, would give way under some unusual vibration, and the legal minimum would be increased another step,— to thirteen inches, or a brick and a half. This is thick enough to resist any strain likely to come upon the party walls of ordinary buildings, but attention began then to be called to a new point. It was observed that carpenters, in laying the floor-beams of two adjoining houses under construction at the same time, instead of troubling themselves to cut off the ends of the beams, so as to secure a partition of brick between the corresponding timbers in the

two houses, would, if they had a twelve-inch wall to lay them on, leave them of the full length, often allowing them to overlap in the wall. Hence, if one of the houses took fire, the flames would often communicate, by means of the combustible floor-beams, from the burning building to the next one, although they were supposed to be separated by a foot of fire-proof material. The insurance companies have the credit of first noticing this, and of exerting their influence to have the thickness of party walls increased by force of law. However this may be, the increase was made, and even added to, until the minimum legal thickness for such walls became, and still remains, in most of our cities, absurdly in excess of the requirements of sound construction. This, however, is not all. The standard brick party wall having been established, of such diameter that the most careless framer would not be likely to have two beams meet in the middle of it, the law-makers naturally thought their task was done; and so it would, perhaps, have been if it had not occurred to some architect to increase the window space in the front of one of his buildings by using iron for the supports, instead of brick. His natural impulse in such a case would be to calculate the necessary strength of his columns and lintels, and combine them firmly and elegantly, keeping in mind the amount of material required, so as neither to waste it nor make his construction too light. In this, however, he found no encouragement from the law-makers. To them a wall was a wall; and having gone through so much trouble to establish the dimensions of brick party walls, they could not be expected to do their work over again because some one wished to build walls of something else than the standard material. And, in point of fact, they did not; and to this day an iron front in New York, whether composed of piers with attached columns, or slender shafts with webs cast between them, must be of the same thickness,—that is, must occupy the space between two planes at the same distance apart, as is required by law for brick walls in the same situation. It is true that in New York there was perhaps originally some excuse for this curious regulation, in the fact that the earliest iron fronts were often mere facings, filled in at the back with brick work, which constituted the real wall. But this construction has long gone by, while the rules founded upon it remain.

Another instance of the same want of pliability of the present over-particularized building laws is to be noticed in the Boston regulations, which prescribe that the openings in a wall shall in no case exceed one-half its area. This seems to be a relic of the classical tradition that, for appearance' sake, the area of the solids and the voids in a wall

should be equal; but it is very much opposed to the modern system of construction of mercantile buildings, where the first consideration is ample lighting for every story. In New York, where the art of mercantile building is more highly developed than anywhere else in the world, no such regulation is known, and structures are erected in brick and stone, as well as iron, which even on corners present a much larger area of voids than of solids, and yet are perfectly strong and substantial. With iron construction, which consists wholly of columns and lintels, the rule is so obviously absurd that the Boston Inspector of Buildings uses the discretion allowed him by law in uniformly waiving this provision.

Besides being too rigid, and therefore not easily applied to the new materials and systems of construction which rapidly follow each other in this country, our building laws, like those of other places, suffer from the spasmodic and hasty way with which they are generally amended. When builders and architects have suffered as long as they are willing the compression of the legal shell which their art has outgrown, the usual way in our cities is for a public meeting to be called, by invitations sent to builders, architects, and insurance men; who assemble, and confer together, usually with the assistance of the principal officials of the local Department of Buildings. Some awkwardness or abuse is cited, and an amendment, intended to cure it, hastily adopted, and the meeting adjourns, having done only a small part of what it intended, and having done that badly. The amendments are presented to the State Legislature by a paid lobbyist, and passed without criticism, often to the injury, rather than the benefit, of the existing statute. From this cause, rather than from deliberate intention, come the singular discrepancies between the regulations of different towns; a construction prescribed in one being sometimes absolutely prohibited in another at a little distance, while modes of building enjoined upon architects and contractors under heavy penalties one year, are often forbidden, under the same penalties, a few months later, in the same town.

The simplest method of avoiding these annoying and costly inconsistencies of the law would evidently be to clothe the Inspector of Buildings with great discretionary power. A good deal of discretion is always left to him in the innumerable details for which the law does not provide, but in those which are specifically prescribed he has no option; and, as the New York Inspector once told the writer, he is obliged to compel owners to put millions on millions of bricks every year where they are of no use whatever, and occupy valuable space which might be saved; while scores of the grossest errors in construction, which do not

happen to be covered by the law, can be committed with impunity unless the inspector is quick enough to detect them. To do this requires great skill in reading plans, and experience and intelligence in comprehending at a glance what follows from their indications. In New York it is necessary to place permanently on file in the Inspector's office copies of the working drawings and variations from them, after they have been approved, are severely punished; but in other towns it is usual to submit a set of plans for examination, and carry them away again after the permit for their execution is granted. With such skillful and experienced inspectors as are now in charge of the Building Departments in our large cities, bad plans rarely receive the indorsement of approval; but good plans are too often badly carried out, for the reason that the amount of work placed upon the deputy inspectors is far too great, even if they were experts in building, which in New York is not always the case. When it is considered that a deputy inspector is usually expected to supervise the construction of at least thirty or forty buildings in process of erection at the same time, it is obvious that there are plenty of opportunities for dishonest builders to use bad mortar in their work, or to make party walls four inches thick in the stairways, by imitating the bonding with half bricks, or to lay drain-pipes which extend only two feet from the visible end, or screw fictitious ventilators on the roof-boards, or practice any other of the successful deceptions known to that class; while, as the official inspection to some extent removes responsibility from the architect, it is doubtful if it is of any great value.

STEAM-ENGINE TESTS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

BY A. J. PURINTON, S.B.

THESE tests, a table of which follows, were made as a part of the regular work of the students in Mechanical and Electrical Engineering during the third and fourth years of the course.

The engine tests are carried on upon three engines, two of which, the Porter-Allen and Harris-Corliss, are in the Mechanical Engineering Laboratory, and the third, a Brown, is at the Institute Shops.

The Porter-Allen engine, having a cylinder 10 inches by 20 inches, and rated at 80 horse-power, at 230 revolutions per minute and 80 pounds pressure, is used to run the ventilating fan of the new building, and

the machinery in the Mechanical and Mining Engineering Laboratories, together with the dynamos of the Electrical Department. Its speed during the tests was only about 200 revolutions per minute.

The valve-gear on this engine was invented by John F. Allen, and gives a positive motion and a constant lead to the valves, which are four in number. The two admission-valves are on one side of the cylinder, and the two exhaust-valves on the other, all being of the gridiron, or multi-port type, giving four openings into the cylinder for each valve.

The two admission-valves are upon separate spindles, both of which receive their motions from a rod, one end of which is fastened to a block lying in a slot in a vibrating link actuated by the eccentric, and the other end to a lever to which the valve-stems are pivoted.

The position of the block in this slot is regulated by the governor, and the change in position varies the travel of the valves, and consequently the cut-off.

The two exhaust-valves are fastened to one spindle, and are moved by means of a rod, one end of which is pivoted to a fixed point in the vibrating link, and the other to the valve spindle, thus giving a constant release and compression.

The Harris-Corliss engine is used for experimental purposes alone, and drives a friction brake, by which the load can be increased to the capacity of the engine.

This engine has a cylinder 8 inches by 24 inches, and is rated at 16 horse-power, running 60 revolutions per minute, with 75 pounds pressure.

It has four valves, the two for admission being above the cylinder, and the two exhaust-valves below. The valves and valve-gear are of the well-known Corliss type, giving a constant lead, release, and compression.

An automatic cut-off governor was used in all the tests except those marked * in the table, during which the governor was disconnected, the cut-off fixed, and the engine belted to a shaft to which the Porter-Allen was also connected, the latter governing for both.

By this means the Harris-Corliss was made to do a constant amount of work, provided the boiler pressure remained constant.

The tests marked † in the table were made with the throttle-valve partly closed, while during the others it was wide open.

The Brown engine, used to drive the machinery at the shops, is rated at 40 horse-power, making 60 revolutions per minute with 60 pounds pressure, and has a cylinder 11 inches by 20 inches.

It has four valves of the gridiron type, which are moved by means of

a revolving shaft at right angles to the crank shaft, from which it takes its motion.

This shaft extends back to the cylinder, and carries two eccentrics, which, by means of eccentric rods, operate the admission-valves, and two positive motion cams which move the exhaust-valves by means of a vibrating arm pivoted to the spindle of each valve.

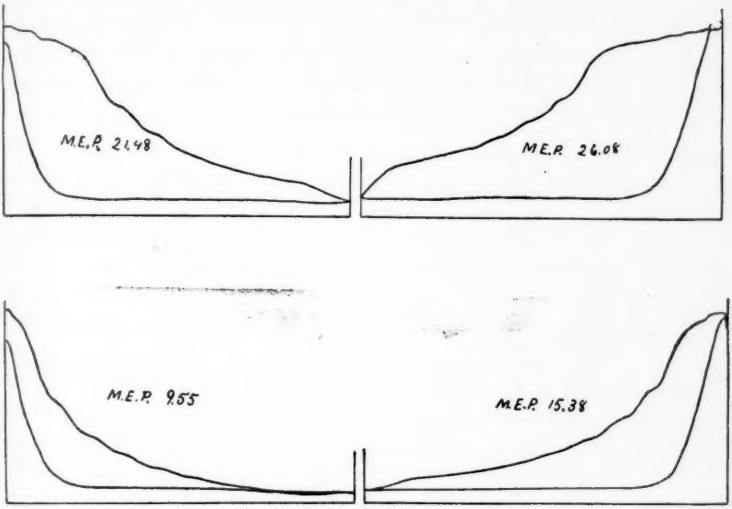


FIG. 1.

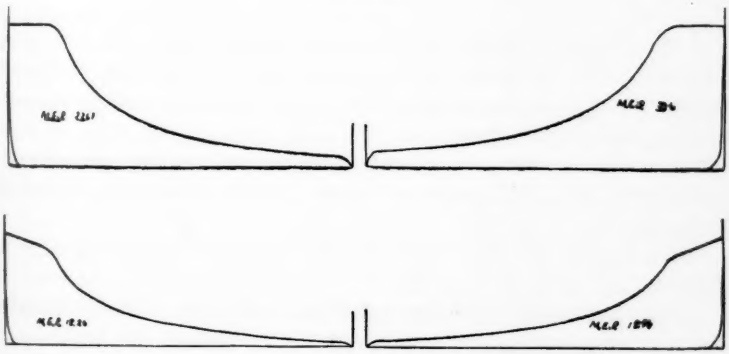


FIG. 2.

The admission-valves move vertically at one side of the cylinder, and the exhaust-valves horizontally under it.

On this engine, also, the lead, release, and compression are constant,

Figs. 1 and 2 each show two pairs of cards taken from the Porter-Allen and Harris-Corliss engines respectively.

The lower pair in Fig. 2 was taken during one of the tests marked † in the table,— that is, with the throttle-valve partially closed.

The method of making and working up the tests here is as follows:—

The exhaust steam from the two engines in the Mechanical Engineering Laboratory passes, under atmospheric pressure, into a surface condenser, and thence into a tank on platform scales, where it is weighed.

The amount of steam used by the Brown engine at the Shops, is ascertained by weighing the feed-water of the boiler, the steam during these tests being used only by the engine.

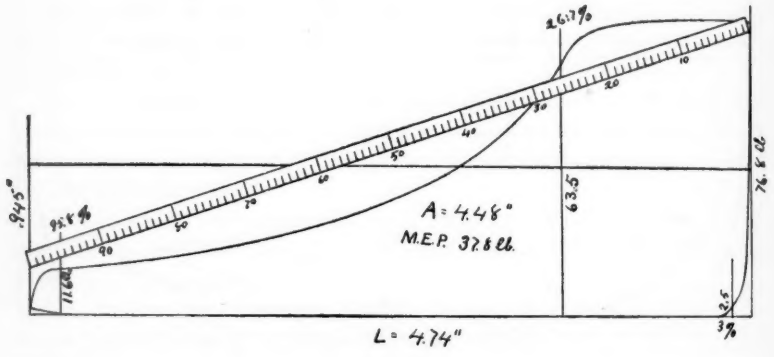


Fig. 3.

A gong is struck at regular intervals of five or ten minutes each, when indicator cards are taken, one from each end of the cylinder; also the weight of the tank and contained water, the boiler pressure, reading of counter, and time of gong.

In this way the amount of water accumulated during the interval is ascertained, and the number of revolutions of the engine during the same time.

These results are then recorded upon a blank log furnished for the purpose.

In working up the cards the area is first measured with a planimeter, tested to insure its accuracy, after which five ordinates are drawn,—one at each end, one at cut-off, one at release, and one at compression, as shown in Fig. 3.

The length is then measured, and the area divided by it, giving the average height of the diagram, which is the altitude of the rectangle in

Fig. 3, the area of the rectangle being the same as that of the diagram. This height, in inches, is multiplied by the number of the spring, which gives the mean effective pressure.

The mean back pressure, if any, may be found in the same way,— that is, by measuring the area included between the atmospheric and back pressure lines and the ordinates at the exhaust end and compression, dividing this by the distance between the two ordinates, and multiplying by the spring.

If, however, the back pressure is nearly constant, as was the case in these experiments (Fig. 1), it may be measured directly upon an ordinate drawn at the middle of the back pressure line.

The scale laid across the diagram (Fig. 3) shows the method of finding the per cent of the stroke at which cut-off, release, and compression take place.

The scale is so graduated that 100 divisions will reach diagonally across, the zero division being on one extreme ordinate, and the 100 division on the other; the positions of the points on the scale where the intermediate ordinates cross it, give the per cent of the stroke at which each takes place.

All these results are then recorded upon the log, and the average taken for the cards of each end, which gives two average cards for the whole test; and from these two average cards the final results are calculated.

The piston displacement, *i. e.*, the area of the piston multiplied by the stroke, both expressed in feet, clearance, given in terms of the piston displacement, and constant (horse-power for one pound mean effective pressure, and one revolution per minute), having been determined beforehand, do not vary for any one engine.

The horse-power for each end of the cylinder is obtained by multiplying the constant by the mean effective pressure for that end, and this product by the number of revolutions per minute.

The total horse-power is found by adding the horse-power for the two ends together. To find the weight of steam at cut-off, its volume must first be found.

The per cent of the stroke at which cut-off takes place is added to the per cent of clearance, and the sum multiplied by the piston displacement, giving the volume of the steam which expands as the piston moves onward.

Recorded upon the log is the pressure above the atmosphere of the steam; and to this the atmospheric pressure, found from the barometer, is added, giving the absolute pressure above a vacuum of the steam at

cut off. Multiply this volume by the weight of a cubic foot of saturated steam, corresponding to this absolute pressure, and the product will be the weight of steam in the cylinder per stroke at cut-off.

The weight per revolution is found by adding the weight per stroke for the two ends of the cylinder.

The weight at release, and at compression, is found in the same way.

The weight of water per revolution, shown by the tank, is obtained by dividing the total weight of water by the whole number of revolutions during the test.

The weight shown by the indicator, is found by subtracting from the weight of steam per revolution at release, the weight at compression per revolution.

To find the weight of water per hour, the weight per revolution is multiplied by the number of revolutions per hour. The quotient, obtained by dividing this last by the total horse-power, will give the water per horse-power per hour.

Adding to the weight of water per revolution by the tank, the weight of steam at compression per revolution shown by the indicator, will give the weight of the mixture of steam and water in the cylinder per revolution.

In making these calculations, it is assumed that there is no water present in the cylinder at release, and that the steam is saturated. There is, however, some water present, as in all the experiments the weight of water given by the tank is greater than that shown by the indicator. It is assumed also that the steam at compression is saturated, and that there is no water present at that point,—which seems to be a fair assumption, as the steam in the exhaust pipe has shown when tested only about four per cent priming.

To get the pounds re-evaporation in the cylinder per hour, subtract the weight of steam at cut-off from the weight at release per stroke for each end of the cylinder, add the two, and multiply the sum by the revolutions per hour. Divide this last by the total horse-power, and the quotient will be the pounds re-evaporation per horse-power per hour.

Some of the results of the tests upon the Porter-Allen and Harris-Corliss engines have been plotted, and curves drawn, which show the average of the results.

The conditions under which the tests upon the Brown engine were made vary so little, that the results have not been plotted.

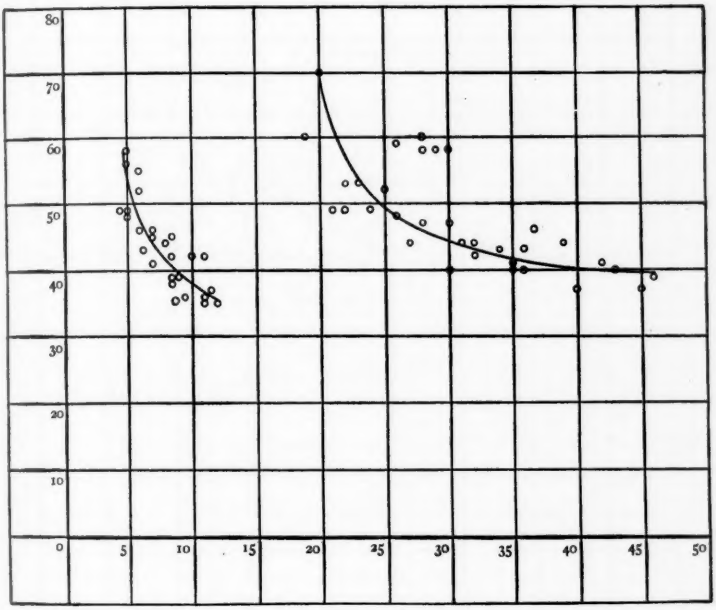


FIG. 4.

Abscissæ — Total H. P. Ordinates — Water per H. P. per hour.

Fig. 4 shows two curves, the right-hand one being drawn from the results of the Porter-Allen tests, and the left-hand one from the Harris-Corliss. The points are plotted with the total horse-power for abscissæ, and pounds of water per horse-power per hour for ordinates.

The left hand curve is very similar to the other as far as it goes, and the two show very clearly that less water per horse-power per hour is used as the power increases, and that the efficiency increases very rapidly at first.

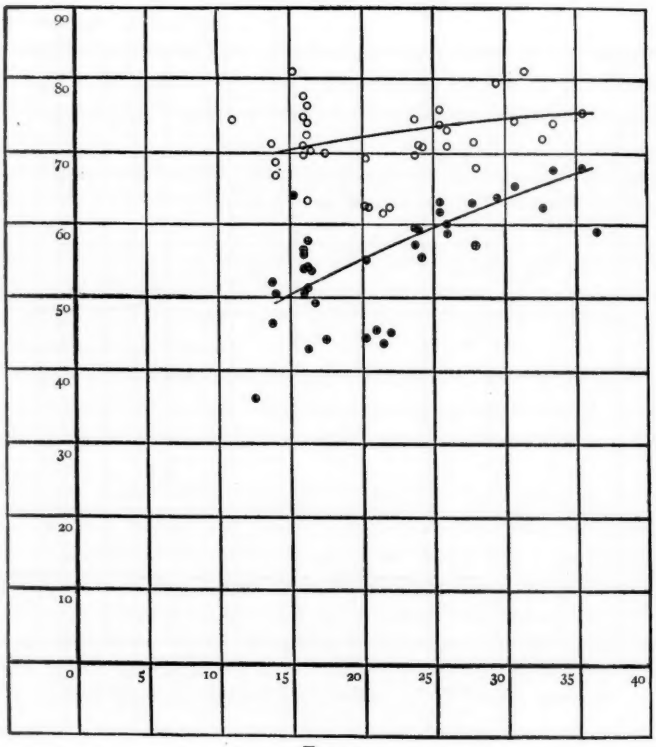


FIG. 5.

Abscissæ — Mean apparent cut-off. Ordinates — Per cent of Mixture in Cylinder, accounted for by Indicator as Steam.

In Figs. 5 (Porter-Allen) and 6 (Harris-Corliss) the abscissæ represent the per cent of mean apparent cut-off, and the ordinates the per cent of the mixture of steam and water in the cylinder, accounted for by the indicator as steam, at cut-off (lower curve) and release (upper curve).

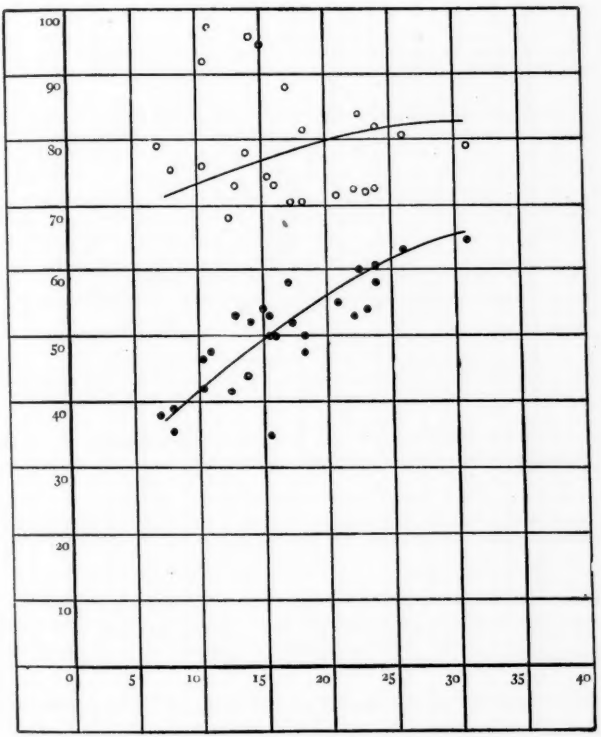


FIG. 6.

Abscissæ — Mean apparent cut-off. Ordinates — Per cent of Mixture in Cylinder, accounted for by Indicator as Steam.

The two pairs of curves are very similar, and show that the per cent of the mixture, accounted for by the indicator as steam, increases very nearly uniformly as the cut-off is lengthened, and that the per cent accounted for at release is greater than that at cut-off.

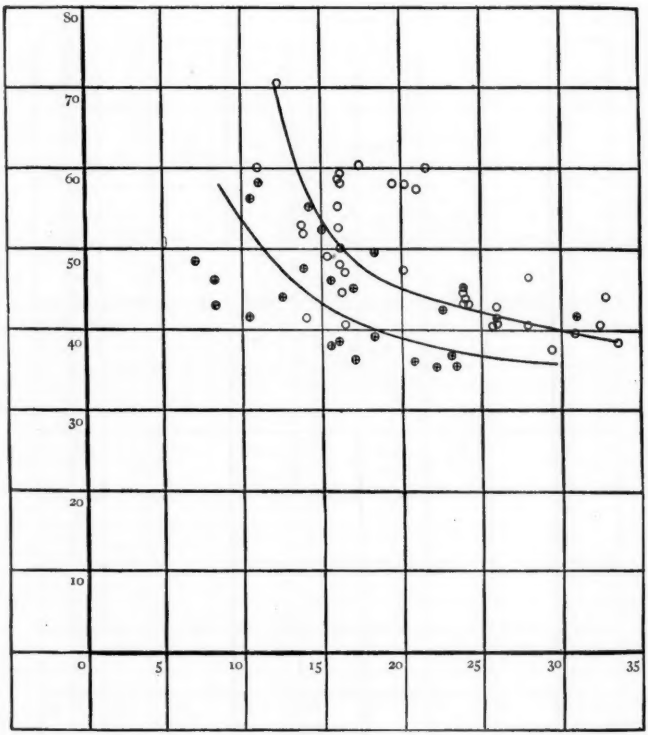


FIG. 7.

Abscissæ — Mean apparent cut-off. Ordinates — Water per H. P. per hour.

In Fig. 7 the per cents of mean apparent cut-off have been taken as abscissæ, and pounds of water per horse-power per hour for ordinates. These curves, the right hand being from the Porter-Allen tests, and the left hand from the Harris-Corliss, are very similar to those of Fig. 4, as might be expected, as the power increases as the cut-off is lengthened, other conditions being the same; but in this case (Fig. 7) the curves lie much nearer together.

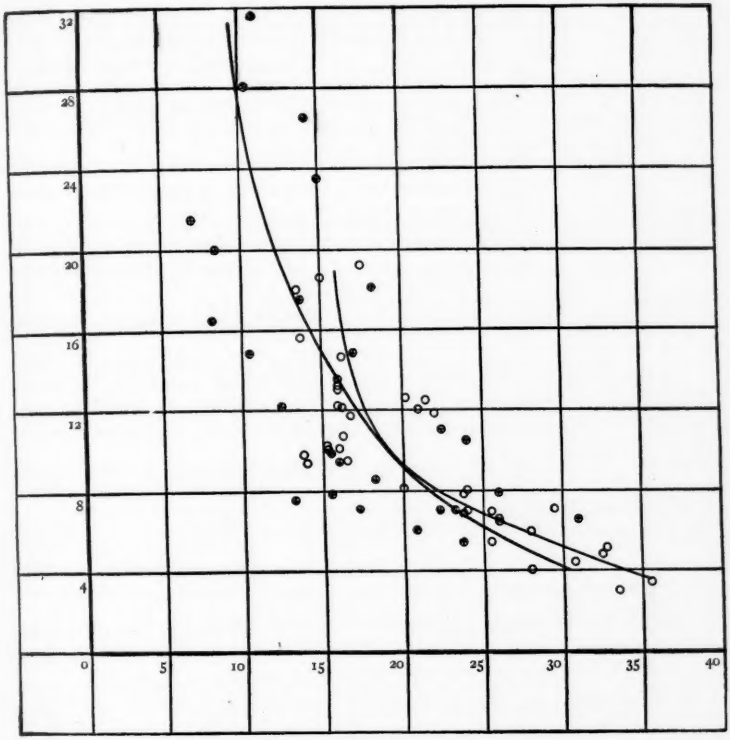


FIG. 8.

Abscissæ — Mean apparent cut-off. Ordinates — Re-evaporation per H. P. per hour.

The curves in Fig. 8 are drawn with per cents of mean apparent cut-off as abscissæ, and pounds re-evaporation in the cylinder per horse-power per hour as ordinates.

The right hand curve is from the Porter-Allen tests, and the left hand from the Harris-Corliss.

It is very noticeable in each of Figs. 7 and 8 how nearly alike the curves from the two engines are, and perhaps more noticeable as one is a high speed engine, running at 200 revolutions per minute, and the other a low speed, running at 60 revolutions per minute.

In the following table the tests have been divided into three groups, as may be readily seen, and each group arranged according to the magnitude of the horse-power developed.

The numbers before the tests indicate the order in which they were made.

Test of Porter-Allen Engine.

No. of Test.	Duration. Min.	Boiler Press.	Total H. P.	Revolutions per Minute.	Barometer. Ins.	Crank End.										Head End.									
						Initial Press.	Pressure at Cut-off.	Pressure at Release.	Pressure at Comp.	Per cent Cut-off.	Per cent Release.	Per cent. Comp.	M. E. P.	M. B. P.	H. P.	Initial Press.	Pressure at Cut-off.	Pressure at Release.	Pressure at Comp.	Per cent Cut-off.	Per cent Release.	Per cent Comp.	M. E. P.	M. B. P.	H. P.
82	85	73.66	18.069	198.85	29.84	65.92	53.06	5.24	7.19	17.77	90	20	14.08	2.95	10.910	69.90	49.53	2.72	8.25	14.40	90	20	8.96	3.20	7.160
228	48	73.30	19.344	198.64	30.24	65.50	42.83	5.83	10.83	15.70	90	15	13.03	.....	9.991	67.50	33.42	3.58	7.14	19.20	87	15	11.83	.....	9.353
81	85	73.93	19.349	194.92	30.38	72.40	66.17	7.28	9.52	13.34	90	10	15.24	3.97	11.470	71.00	64.32	2.88	8.74	8.83	90	10	10.15	3.64	7.880
250	60	72.30	20.100	198.58	29.75	65.60	51.90	8.37	9.36	15.43	85	15	15.70	3.30	12.034	65.90	51.14	2.71	6.71	9.39	85	15	10.21	2.80	8.070
87	75	73.70	21.421	202.36	29.94	73.70	60.60	6.60	7.70	18.50	90	10	17.34	3.70	13.550	74.40	49.80	1.90	6.60	12.10	90	10	9.77	3.60	7.870
83	75	72.40	21.670	195.70	30.07	69.06	63.14	8.06	6.41	20.40	90	20	21.32	.....	16.110	64.86	63.70	0.07	7.15	7.05	90	20	7.13	.....	5.560
205	65	68.87	22.422	200.49	30.18	67.65	54.18	9.30	11.73	20.60	90	16.5	17.27	4.88	13.365	66.42	56.29	3.23	5.81	11.20	85	17.5	17.27	4.48	9.057
149	75	73.16	23.040	198.16	29.98	69.84	56.28	7.99	17.97	18.12	90	15	16.12	4.06	12.330	69.62	53.94	3.28	9.81	14.09	90	15	13.58	3.09	10.710
113	70	72.01	23.750	195.27	29.95	70.20	56.83	7.80	10.30	19.47	95	20	18.01	4.66	13.580	71.17	62.90	3.57	5.77	12.86	95	20	13.07	3.70	10.170
231	60	73.47	25.242	196.40	29.80	68.70	60.09	11.30	10.47	18.83	87	15	20.15	5.44	15.276	69.03	61.47	5.50	8.63	8.74	85	15	12.75	4.60	9.966
90	80	75.10	25.576	199.49	30.43	72.40	62.90	7.08	15.36	17.00	90	15	17.26	4.44	13.294	75.20	61.20	5.65	13.00	15.05	90	15	15.46	4.27	12.282
170	95	71.60	25.645	198.87	29.95	68.71	54.74	7.13	15.52	17.91	88	15	16.21	3.05	12.443	69.07	56.24	9.24	12.37	14.69	88	15	16.68	3.08	13.202
93	85	74.79	27.146	198.21	29.93	72.47	65.42	9.32	15.20	18.00	90	15	19.08	5.78	14.600	73.36	63.58	6.57	13.29	14.49	90	15	15.89	4.99	12.550
95	75	74.67	27.657	197.89	29.80	70.92	62.47	8.35	13.44	17.62	90	15	18.60	4.40	14.212	73.03	64.81	6.41	13.66	15.25	90	15	17.06	4.34	13.445
187	80	72.82	27.920	196.93	30.09	70.72	62.78	12.11	25.39	19.94	90	10	22.44	4.94	17.057	67.80	55.72	4.81	16.22	12.44	85	10	13.86	3.49	10.863
173	90	69.40	28.450	198.05	30.07	66.94	48.19	9.11	15.96	23.85	88	15	18.82	3.52	14.380	67.20	49.55	10.73	12.50	19.28	88	15	17.85	3.38	14.070
181	85	73.31	28.747	198.76	30.24	70.31	53.75	9.31	17.72	21.79	88	15	18.96	4.28	14.547	71.03	53.11	11.00	15.44	18.42	88	15	17.95	4.06	14.200
102	70	73.80	29.635	190.24	28.34	69.80	46.60	12.50	17.16	33.20	90	15	21.23	5.50	15.590	65.90	41.50	9.40	13.10	31.80	90	15	18.53	5.16	14.040
178	85	72.26	29.377	198.72	30.02	68.88	53.41	10.00	16.69	22.86	88	15	19.48	4.38	14.943	69.22	53.19	11.11	14.19	19.00	88	15	18.25	4.38	14.434
180	75	73.60	29.887	197.40	30.22	70.16	53.40	10.30	16.95	23.64	88	15	19.84	4.50	15.117	70.93	51.25	11.70	14.20	20.18	88	15	18.80	4.25	14.770
103	65	73.74	30.212	198.41	29.87	69.31	58.71	11.80	17.36	21.80	85	15	20.60	.....	15.780	71.30	59.95	8.82	13.01	18.48	85	15	18.26	.....	14.430
160	95	72.16	31.297	196.05	30.24	69.82	50.57	11.72	16.95	27.02	88	15	22.29	3.82	16.838	70.42	50.07	6.17	9.20	20.68	88	15	18.53	2.65	14.459
91	80	74.94	31.680	197.35	30.45	72.23	72.03	7.47	11.75	11.94	90	15	22.21	1.31	16.920	71.46	61.06	5.24	8.34	15.88	90	15	18.78	1.08	14.760
152	85	72.60	31.919	198.42	30.67	70.20	51.40	11.40	16.80	27.12	90	15	22.62	4.00	17.325	70.40	50.10	5.79	9.00	20.79	90	15	18.48	3.10	14.594
154	75	73.30	34.104	196.20	30.74	71.19	51.44	13.25	17.69	29.00	88	15	24.05	4.44	18.214	70.93	48.03	7.30	9.20	23.21	88	15	20.35	3.30	15.890
214	61	72.49	34.419	195.60	29.34	69.36	56.07	15.29	7.64	27.36	88	20	25.81	4.57	19.487	68.14	43.79	6.43	3.64	20.93	88	20	19.18	4.20	14.932
157	80	73.45	34.708	195.26	30.14	71.44	49.89	13.77	16.70	29.89	88	15	24.83	4.21	18.715	71.20	50.90	7.50	8.63	21.90	88	15	20.58	3.09	15.993
156	100	74.03	34.970	195.50	30.36	72.19	56.59	14.22	16.69	28.90	88	15	25.39	4.82	19.160	71.30	51.90	7.65	9.41	22.30	88	15	20.32	3.75	15.810
229	60	73.80	35.964	195.28	29.83	72.60	62.90	19.10	11.10	27.60	85	15	26.82	7.10	20.217	70.10	53.80	8.50	8.30	20.10	87	15	20.36	4.10	15.747
222	45	71.83	36.000	195.38	29.57	69.42	55.56	16.87	14.50	29.93	88	16.5	26.55	5.25	20.020	69.05	53.05	8.85	6.90	21.30	85	16.5	20.56	3.70	15.980
97	55	74.73	36.438	199.49	29.74	72.35	63.04	12.37	12.54	13.66	90	15	23.92	5.08	18.420	73.25	63.20	9.16	11.66	19.98	90	15	22.67	3.91	18.018
215	60	72.20	37.081	194.88	29.34	69.60	53.86	16.79	8.50	33.44	90	20	27.59	.....	20.754	70.07	53.80	10.07	7.93	22.36	85	15	21.05	.....	16.327
218	60	72.83	39.260	193.30	29.97	71.86	53.14	19.57	10.86	38.00	89	20	28.50	7.43	21.265	70.57	51.81	12.57	8.43	27.71	85	18	23.39	6.40	17.995
224	60	72.04	39.674	194.83	29.56	69.79	48.14	17.86	9.79	34.57	87	15	29.41	5.57	22.118	68.71	49.42	11.21	9.36	24.28	85	15	22.64	4.93	17.556
105	70	73.98	42.121	196.11	30.15	71.70	61.90	15.90	15.50	30.58	90	15	29.26	4.60	22.150	71.50	59.90	11.60	9.70	25.10	90	15	25.56	4.15	19.970
184	60	72.30	43.494	193.47	30.45	70.00	60.21	20.71	34.50	37.10	90	10	31.30	5.93	23.374	69.10	60.14	13.43	18.80	24.59	85	10	26.13	5.34	20.120
185	80	73.10	45.430	193.08	30.12	70.70	54.29	20.22	31.17	39.80	90	10	32.84	4.61	24.475	70.61	48.28	12.98	16.39	31.42	85	10	27.27	3.88	20.955
106	75	72.96	46.113	193.50	29.81	71.72	60.13	17.99	15.03	33.90	90	15	30.32	5.25	22.660	71.13	58.50	15.59	13.36	32.94	90	15	30.43	4.45	23.460

Test of Porter–Allen Engine.

No. of Test.	Water per H. P. per Hour.		Weight of Steam per Stroke.						Weight of Mixture in Cylinder per Revolution.	Per cent of Mixture in Cylinder accounted for by Indicator as Steam.		Difference.	Lbs. Re-evaporation per H. P. per Hour.
			Crank End.			Head End.							
	By Tank.	By Indicator.	Cut-off.	Release.	Compression.	Cut-off.	Release.	Compression.		Cut-off.	Release.		
82	55.356	37.263	.033679	.042881	.012165	.028123	.038869	.013159	.109160	56.620	74.890	18.270	13.171
228	60.161	38.036	.026400	.044440	.011910	.026740	.039850	.010640	.120190	44.208	70.123	25.915	19.190
81	59.939	42.240	.032488	.047484	.008705	.024866	.039710	.008608	.116474	49.242	74.861	25.619	18.037
250	70.680	36.400	.029700	.046320	.011210	.021760	.036580	.010270	.140740	36.560	58.900	22.340	18.630
87	48.980	38.061	.039862	.045641	.007936	.025042	.037247	.007807	.102153	63.538	81.143	17.605	10.193
83	52.980	30.847	.042667	.048811	.012351	.021668	.033523	.013063	.123195	52.222	66.833	14.611	9.754
205	48.764	34.974	.038211	.051330	.013166	.026216	.038214	.011189	.115245	55.905	77.700	21.795	13.475
149	52.8737	32.035	.035602	.048545	.014950	.029635	.040261	.011777	.129169	50.505	68.752	18.247	12.163
113	48.9940	32.967	.037850	.050610	.014380	.031230	.042920	.012300	.126030	54.812	74.212	19.400	12.058
231	52.056	34.000	.038450	.053240	.011660	.023950	.042460	.011200	.134370	46.440	71.220	24.780	15.550
90	48.385	30.700	.037018	.047158	.013921	.034145	.045668	.011331	.130617	54.482	71.067	16.585	10.138
170	59.169	32.808	.034547	.045800	.013887	.031473	.051516	.012915	.153962	42.882	63.207	20.325	14.561
93	44.283	31.162	.039686	.051146	.013744	.034192	.047053	.013324	.128148	57.654	76.634	18.980	10.655
95	47.000	29.726	.037671	.049067	.012953	.035956	.046584	.013458	.135898	54.177	70.383	16.206	9.455
187	58.313	31.998	.041600	.056850	.013820	.027880	.041270	.011170	.135120	51.420	72.620	21.200	12.122
173	59.660	32.349	.039338	.049788	.013959	.035960	.054618	.012997	.169786	43.819	61.494	17.675	12.534
181	58.035	31.720	.039707	.050358	.014894	.035673	.055346	.014349	.169133	44.569	62.497	17.928	12.580
102	40.435	30.850	.049312	.055927	.014251	.045573	.051303	.012888	.132120	71.819	81.163	9.344	4.755
178	57.631	31.939	.040983	.051493	.014404	.036504	.055346	.013743	.170147	45.542	62.793	17.251	11.913
180	58.313	31.998	.042142	.052275	.014472	.037200	.056733	.013792	.175410	45.233	62.141	16.908	11.756
103	47.144	30.212	.039788	.053100	.014658	.041693	.048954	.013181	.147430	55.264	69.214	13.950	8.106
160	44.318	27.989	.045121	.055063	.014563	.037331	.045570	.011554	.144104	57.217	69.835	12.618	6.829
91	41.604	25.862	.032223	.047995	.012413	.035429	.044782	.011165	.134888	50.155	68.780	18.625	9.390
152	43.842	28.413	.045936	.056107	.014590	.037618	.046208	.011548	.143740	58.129	71.180	13.051	6.998
154	42.716	27.656	.048568	.058443	.014971	.039787	.048295	.011648	.150369	58.750	70.970	12.220	6.345
214	42.922	28.175	.048890	.061130	.012780	.034000	.045200	.010920	.149580	55.415	71.086	15.671	7.993
157	40.733	27.483	.048524	.058947	.014434	.039478	.048173	.011269	.146343	60.135	73.199	13.064	6.454
156	40.440	27.690	.051841	.060012	.014472	.040676	.048681	.011671	.146703	63.066	74.090	11.024	5.426
229	43.015	30.300	.058870	.066720	.011990	.038380	.049350	.011050	.155080	59.490	74.840	15.350	7.757
222	40.371	28.705	.052379	.064397	.014318	.039664	.048736	.010664	.148962	61.790	75.950	14.160	6.868
97	40.479	27.603	.030564	.056568	.012163	.042066	.051788	.012173	.147547	49.225	73.441	24.216	11.737
215	46.466	29.096	.056098	.065392	.013251	.041571	.050908	.010780	.171384	56.980	67.860	10.880	5.874
218	44.065	29.432	.062220	.070700	.014690	.047720	.056360	.012740	.176590	62.260	71.950	9.690	5.055
224	37.380	28.340	.053220	.065580	.011310	.041760	.053330	.011430	.149600	63.490	79.490	16.000	7.051
105	40.541	26.928	.058060	.064410	.013920	.049660	.057660	.011760	.170800	63.067	71.470	8.403	4.009
184	39.775	27.676	.067107	.074141	.016802	.049083	.058490	.012128	.177930	65.290	74.520	9.230	4.388
185	37.013	26.330	.065871	.072870	.015680	.050950	.057310	.011230	.172060	67.890	75.660	7.770	3.407
106	38.540	26.872	.061823	.068206	.013645	.059986	.065479	.013329	.180022	67.663	74.260	6.597	2.991

Test of Harris-Corliss Engine.

No. of Test.	Duration. Min.	Boiler Press.	Total H. P.	Revolutions per Minute.	Barometer. Ins.	Crank End.										Head End.									
						Initial Press.	Pressure at Cut-off.	Pressure at Release.	Pressure at Comp.	Per cent Cut-off.	Per cent Release.	Per cent Comp.	M. E. P.	M. B. P.	H. P.	Initial Press.	Pressure at Cut-off.	Pressure at Release.	Pressure at Comp.	Per cent Cut-off.	Per cent Release.	Per cent Comp.	M. E. P.	M. B. P.	H. P.
†*201	75	69.64	4.4673	59.84	30.07	48.12	27.72	-0.25	1.75	17.50	96	2.5	11.74	.....	2.0795	48.17	26.66	0.40	3.23	19.00	96	2.5	13.04	.....	2.3878
130	75	68.83	4.9352	62.83	29.92	67.59	62.03	5.91	20.16	10.72	98	2.	12.84	8.03	2.3905	67.72	62.28	6.50	18.28	10.53	98	2	13.23	8.44	2.5447
123	75	73.09	5.0049	62.87	30.18	71.19	65.41	8.09	26.84	10.06	98	2.	11.41	10.84	2.1256	71.39	66.71	9.07	21.25	12.11	98	2	14.96	11.43	2.8793
137	75	73.40	5.1100	64.25	29.56	70.60	54.44	0.18	9.60	7.10	98	2.	13.16	.....	2.5230	70.90	55.80	1.10	7.78	7.08	98	2	14.40	.....	2.5870
†*209	70	69.70	5.2432	59.86	29.80	55.37	38.37	0.50	1.42	12.50	96	2.5	13.46	.....	2.3840	54.80	38.96	2.55	3.03	15.00	96	2.5	15.61	.....	2.8592
124	75	72.44	5.7966	62.08	30.52	70.91	65.59	9.91	29.08	12.68	98	2.	13.12	12.37	2.4140	70.64	66.89	11.22	23.96	15.77	98	2	17.80	12.67	3.3830
125	85	72.70	6.0089	62.05	30.24	71.44	66.25	9.97	28.58	13.10	98	2.	14.25	11.86	2.6200	71.64	64.44	10.36	24.67	17.12	98	2	17.84	12.22	3.3888
138	85	72.97	6.0492	63.65	30.23	70.47	61.72	0.75	10.14	7.61	98	2.	15.01	.....	2.8278	70.91	55.36	2.05	7.59	8.72	98	2	16.54	.....	3.2214
122	80	72.05	6.7436	63.55	29.74	69.68	63.23	1.41	9.88	7.49	98	2.	16.49	.....	3.1054	70.26	61.29	3.21	7.84	9.03	98	2	18.70	.....	3.6382
†*196	65	69.94	7.1860	60.35	30.38	61.17	52.18	2.65	1.30	14.50	96	2.5	19.22	.....	3.4340	60.59	49.22	4.31	4.37	16.50	96	2.5	20.32	.....	3.7520
†139	85	74.67	7.1929	63.33	30.35	70.64	58.06	1.86	9.08	10.05	98	2.	18.09	.....	3.3948	71.03	58.03	3.42	7.83	10.84	98	2	19.59	.....	3.7981
127	80	71.12	7.1940	61.50	30.55	70.53	66.21	7.68	22.50	14.68	98	2.	17.58	9.32	3.2035	70.26	65.44	9.91	21.74	19.09	98	2	21.20	10.03	3.9908
*186	70	72.00	7.8547	60.79	29.99	69.71	60.17	3.65	3.31	10.50	95	2.	19.49	.....	3.5064	70.69	59.55	5.59	6.25	14.50	95	2	23.38	.....	4.3483
†*193	60	72.07	8.2847	59.72	30.26	71.00	64.50	2.50	2.04	11.50	96	2.	20.59	.....	3.6396	70.80	63.30	5.80	4.30	15.00	96	2	25.42	.....	4.6451
†*213	70	72.01	8.5072	59.34	29.37	65.67	59.13	5.11	1.57	16.00	96	2.5	23.60	.....	4.1455	64.53	56.93	6.07	3.37	16.00	96	2.5	24.02	.....	4.3617
†*195	65	72.78	8.5761	60.43	29.79	66.28	59.44	4.24	1.42	14.50	96	2.5	22.41	.....	4.0086	66.10	57.27	6.37	3.58	16.50	96	2.5	24.70	.....	4.5675
131	85	71.83	8.5930	60.75	29.78	70.31	61.11	10.31	23.03	21.20	98	2.	21.63	10.67	3.8930	70.44	60.97	13.68	23.68	26.46	98	2	25.26	11.35	4.6990
126	80	72.65	8.6909	61.30	29.49	71.33	60.78	9.06	24.53	19.08	98	2.	20.90	9.25	3.7965	71.29	58.26	13.35	20.59	26.04	98	2	26.08	10.15	4.8944
†*198	65	67.96	9.0690	60.37	29.57	64.84	55.57	5.03	0.77	17.50	96	2.5	24.35	.....	4.3512	64.46	54.75	7.23	4.46	19.00	96	2.5	25.54	.....	4.7178
*189	70	71.88	9.3149	56.43	28.35	70.14	62.35	5.43	2.21	16.00	96	2.	25.59	.....	4.2790	70.64	65.53	8.46	6.20	18.50	96	2	29.15	.....	5.0359
128	85	71.57	9.9499	60.12	29.23	70.56	61.44	12.22	21.53	23.98	98	2.	25.31	10.08	4.5040	70.83	65.52	15.22	22.75	28.10	98	2	29.60	10.70	5.4459
*202	65	69.39	10.8248	60.74	30.34	68.53	60.34	7.46	1.53	20.00	96	2.5	28.42	.....	5.1095	69.46	60.54	8.54	3.89	21.50	96	2.5	30.75	.....	5.7153
*190	65	69.49	10.9151	60.82	30.18	67.22	60.50	7.38	3.29	20.50	96	2.5	28.75	.....	5.1755	67.68	54.56	8.64	5.90	24.00	96	2.5	30.84	.....	5.7396
129	75	71.17	11.1642	59.40	29.55	70.28	64.69	15.16	21.81	28.12	98	2.	29.32	9.88	5.1600	69.94	62.13	18.63	21.09	34.14	98	2	33.02	10.59	6.0042
148	75	71.75	11.5165	61.69	30.45	70.40	59.62	6.11	9.20	18.01	98	2.	26.20	.....	4.7845	70.60	57.20	12.38	8.63	28.41	98	2	35.66	.....	6.7320
*191	65	71.86	11.8266	60.54	30.83	70.02	61.55	9.02	2.97	23.00	96	2.	31.72	.....	5.6903	70.24	59.86	10.70	7.10	24.50	96	2	33.11	.....	6.1363

Test of Harris–Corliss Engine.

No. of Test.	Water per H. P. per Hour.		Weight of Steam per Stroke.						Weight of Mixture in Cylinder per Revolution.	Per cent of Mixture in Cylinder accounted for by Indicator as Steam.		Difference.	Lbs. Re-evaporation per H. P. per Hour.
			Crank End.			Head End.							
	By Tank.	By Indicator.	Cut-off.	Release.	Compression.	Cut-off.	Release.	Compression.		Cut-off.	Release.		
†*201	49.470	39.662	.014851	.026225	.001798	.016512	.027795	.002873	.066225	47.359	81.570	34.211	18.209
130	56.289	51.397	.017635	.036014	.003338	.020143	.038835	.004223	.081256	46.494	92.116	45.622	28.316
123	58.343	56.328	.017556	.039808	.003948	.023372	.043475	.004595	.085956	47.615	96.890	49.275	31.629
137	48.610	37.533	.011945	.026047	.002356	.014480	.028970	.002911	.069699	37.913	78.935	41.022	21.571
†*209	47.690	36.615	.013985	.026431	.001752	.018338	.031285	.002508	.073890	43.750	78.110	34.360	17.393
124	55.274	52.276	.020970	.043034	.004162	.028362	.047419	.004938	.095118	51.865	95.096	43.231	26.424
125	52.453	49.271	.021638	.042912	.004106	.029272	.045728	.005007	.093773	54.291	94.526	40.235	23.376
138	46.083	34.002	.013820	.027720	.002330	.014040	.031415	.002940	.078100	35.672	75.718	40.046	19.744
122	42.985	31.707	.013887	.028423	.002395	.018009	.032989	.002942	.081360	39.203	75.483	36.280	16.690
†*196	46.085	21.090	.013250	.020570	.001201	.016360	.024390	.001910	.084610	34.996	53.139	18.143	7.735
†139	41.462	30.758	.016043	.029673	.002350	.019519	.033876	.002978	.083815	42.429	75.821	33.392	14.784
127	45.114	39.176	.023696	.039421	.003576	.032263	.045210	.004675	.096208	58.165	87.967	29.802	14.706
*186	44.110	29.285	.016976	.031394	.001797	.024324	.036233	.002760	.099617	41.459	67.887	26.428	12.224
†*193	35.306	27.259	.019190	.030070	.001690	.026160	.037190	.002540	.085860	52.819	73.338	20.519	7.526
†*213	38.685	31.900	.023132	.033584	.001745	.025187	.036904	.002525	.096710	49.963	72.886	22.923	9.278
†*195	38.077	27.884	.021517	.032519	.001751	.025962	.037768	.002580	.094340	50.300	74.467	24.167	9.643
131	45.062	36.320	.030035	.043091	.003590	.039577	.050970	.004862	.114688	60.707	82.029	21.322	10.373
126	42.307	35.048	.027323	.040830	.003712	.037669	.050176	.004476	.108157	60.090	84.142	24.052	11.009
†*198	39.340	27.270	.023782	.033616	.001673	.027926	.039032	.002683	.102852	50.276	70.635	20.359	8.364
*189	36.232	25.087	.023935	.033277	.001617	.030803	.040077	.002716	.104016	52.217	70.682	18.465	6.920
128	41.506	32.862	.033406	.045748	.003431	.043828	.053116	.004719	.122729	62.931	80.555	17.624	7.841
*202	36.071	25.440	.028417	.038138	.001790	.033358	.041877	.002658	.111588	55.360	71.707	16.347	6.141
*190	35.181	25.114	.029040	.037930	.001962	.029680	.041910	.002919	.110181	53.294	72.463	19.169	7.065
129	41.705	32.515	.039984	.050744	.003471	.049752	.059120	.004539	.138650	64.722	79.238	14.516	6.425
148	36.730	25.929	.024772	.036773	.002366	.040203	.049344	.003083	.119720	54.274	71.933	17.659	6.796
*191	35.474	25.242	.032586	.041016	.001805	.036870	.045895	.002917	.120220	57.774	72.294	14.520	5.361

Test of Brown Engine.

No. of Test.	Duration. Min.	Boiler Press.	Total H. P.	Revolutions per Minute.	Barometer. Ins.	Crank End.										Head End.									
						Initial Press.	Pressure at Cut-off.	Pressure at Release.	Pressure at Comp.	Per cent Cut-off.	Per cent Release.	Per cent Comp.	M. E. P.	M. B. P.	H. P.	Initial Press.	Pressure at Cut-off.	Pressure at Release.	Pressure at Comp.	Per cent Cut-off.	Per cent Release.	Per cent Comp.	M. E. P.	M. B. P.	H. P.
268	210	.....	8.737	59.38	30.17	18.61	14.60	0.90	3.80	44.81	100	5	9.69	.....	4.085	18.66	15.43	1.77	2.13	50.50	97	5	10.88	.....	4.652
258	210	36.33	8.998	59.88	30.08	29.20	19.57	0.27	2.88	35.37	100	5	10.26	.....	4.352	26.90	17.20	0.35	1.20	39.80	100	5	10.80	.....	4.646
257	210	40.69	9.148	60.26	30.14	32.60	21.40	-0.01	2.47	29.10	100	5	10.49	.....	4.488	29.78	17.77	0.15	1.63	34.07	100	5	10.74	.....	4.660
265	210	.....	9.712	59.05	30.31	18.32	13.94	2.60	2.65	55.44	100	5	11.45	.....	4.801	17.57	14.75	3.80	1.64	55.87	96.5	5	11.55	.....	4.911
259	210	.....	10.269	60.10	30.10	34.50	25.83	0.00	2.93	24.89	100	5	11.35	0.83	4.843	32.34	24.77	0.00	2.07	27.33	100	5	12.54	0.67	5.426
162	180	41.40	10.597	61.37	29.91	37.00	36.70	0.44	6.30	19.60	98	3	13.42	.....	5.847	36.70	36.50	-0.80	4.80	13.80	97	3	10.75	.....	4.750
164	195	30.06	10.602	59.84	30.29	26.97	24.31	0.56	0.78	29.22	93	6	12.30	.....	5.225	28.02	22.48	0.97	1.49	33.07	93	6	12.48	.....	5.377
263	210	.....	10.726	60.11	30.30	35.00	23.83	0.00	2.63	30.90	100	5	12.83	.....	5.476	30.93	20.73	0.00	4.83	34.13	100	5	12.13	.....	5.250
177	195	28.86	10.947	58.64	30.26	25.97	20.16	3.92	4.01	49.15	100	5	13.01	2.89	5.416	27.04	21.93	4.46	5.70	48.69	100	5	13.10	3.73	5.531
174	180	.....	11.046	59.71	30.24	29.17	27.89	1.80	3.50	29.45	100	4	12.77	1.73	5.414	29.00	27.15	0.64	1.79	30.30	100	7	13.10	0.71	5.632
167	195	.....	11.248	59.63	30.03	26.75	25.42	0.78	1.61	33.12	100	5	12.98	0.41	5.495	27.67	24.33	1.90	2.14	36.11	100	5	13.40	1.08	5.753
172	195	29.95	11.273	59.50	30.14	26.07	22.07	1.71	3.86	39.29	100	4	13.05	1.25	5.512	27.13	21.41	2.17	1.61	40.19	98	8	13.45	0.60	5.761
171	195	.....	11.350	59.70	30.14	27.80	25.60	1.10	3.60	33.10	98	4	12.86	1.10	5.456	28.40	26.00	1.60	1.70	33.20	98	8	13.70	0.70	5.894
262	210	.....	11.469	60.34	30.28	35.70	25.07	0.00	2.13	29.43	100	5	13.52	.....	5.765	31.67	21.60	6.00	3.80	34.80	100	5	13.19	.....	5.704
165	195	29.24	11.471	59.48	30.29	26.49	22.98	2.41	1.21	36.57	93	6	12.39	0.74	5.232	26.89	21.91	3.46	1.54	41.06	93	6	14.57	0.86	6.239
169	195	.....	11.709	59.46	30.08	27.00	24.40	1.90	3.70	35.00	99	5	13.59	1.00	5.737	26.96	24.60	2.40	2.90	36.00	99	5	13.95	0.70	5.972
168	165	.....	11.755	59.60	30.09	28.29	23.83	1.75	3.25	34.89	99	5	13.45	1.60	5.692	29.16	24.87	1.60	2.50	34.60	99	5	14.13	0.68	6.063
176	195	.....	12.092	59.51	30.26	27.70	25.10	2.00	2.77	36.90	100	5	13.69	1.70	5.785	29.30	25.90	3.50	4.00	39.60	100	5	14.72	2.40	6.307
163	120	40.11	15.589	60.36	29.86	36.33	35.00	4.50	6.00	31.70	98	3	19.43	.....	8.327	37.39	36.06	3.00	4.78	25.80	97	3	16.71	.....	7.262

Test of Brown Engine.

No. of Test.	Water per H. P. per Hour.		Weight of Steam per Stroke.						Weight of Mixture in Cylinder per Revolution.	Per cent of Mixture in Cylinder accounted for by Indicator as Steam.		Difference.	Lbs. Re-evaporation per H. P. per Hour.
			Crank End.			Head End.							
	By Tank.	By Indicator.	Cut-off.	Release.	Compression.	Cut-off.	Release.	Compression.		Cut-off.	Release.		
268	64.260	51.400	.05736	.06820	.00657	.06599	.07013	.00572	.16989	72.610	81.420	8.810	6.110
258	54.810	47.930	.05340	.06546	.00625	.05562	.06651	.00541	.14926	73.040	88.420	15.380	9.140
257	54.030	46.760	.04706	.06444	.00612	.04903	.06554	.00556	.14838	64.760	87.600	22.840	13.390
265	64.010	51.670	.06868	.07539	.00621	.07166	.07806	.00559	.18730	74.930	81.930	7.000	4.780
259	52.810	41.180	.04560	.06440	.00627	.04814	.06484	.00570	.16237	57.770	79.600	21.830	12.450
162	53.000	39.440	.04636	.06460	.00563	.03399	.05943	.00490	.16303	49.290	76.080	26.790	15.180
164	44.170	38.790	.05088	.06252	.00624	.05426	.06450	.00623	.14291	73.570	88.880	15.310	7.410
263	45.580	39.430	.05289	.06481	.00620	.05340	.06525	.00660	.13678	71.670	87.700	16.030	7.990
177	62.260	48.380	.07367	.08065	.00665	.07658	.08340	.00687	.20769	72.340	78.990	6.650	4.435
174	47.390	41.230	.05560	.07203	.00572	.05593	.06776	.00696	.15878	70.240	88.040	17.800	9.170
167	49.680	40.830	.05828	.06742	.00581	.06137	.07248	.00571	.16772	71.340	83.410	12.070	6.440
172	52.980	41.290	.06285	.07147	.00581	.06310	.07240	.00764	.18075	69.680	79.580	9.910	5.670
171	54.220	39.720	.05859	.06901	.00574	.05918	.07015	.00768	.18502	63.650	75.210	11.560	6.760
262	49.100	36.970	.05214	.06476	.00603	.05560	.06521	.00627	.16856	63.920	77.110	13.190	6.985
165	52.040	40.710	.06032	.06954	.00640	.06532	.07398	.00625	.17992	69.836	79.770	9.940	5.560
169	48.460	40.470	.05985	.07141	.00652	.06170	.07392	.00596	.17153	70.860	84.730	13.870	7.245
168	47.330	39.330	.05887	.07093	.00651	.05981	.07068	.00583	.16794	70.670	84.320	13.650	6.980
176	50.480	41.290	.06268	.07288	.00624	.06956	.07950	.00633	.18353	72.050	83.030	10.980	5.950
163	47.150	33.590	.06841	.08063	.00555	.05777	.07446	.00493	.21343	59.120	72.670	13.550	6.720

Porter-Allen.	C. E.	H. E.	Harris-Corliss.	C. E.	H. E.	Brown.	C. E.	H. E.
Piston Displacement. Cu. ft.	.8848	.9127	Piston Displacement. Cu. ft.	.6791	.7016	Piston Displacem't. Cu. ft.	1.631	1.650
Clearance .....*	.06092	.05906	Clearance	.03755	.05424	Clearance	.035	.030
Constant	.003861	.003983	Constant	.00296	.00306	Constant	.0071	.0072
* After No. 113.....	.06	.06						

NOTES ON ASSAYING OF LEAD, SILVER, AND GOLD.

BY FREDERICK W. CLARK, S.B.

CHAPTER I.

ASSAYING is a branch of analytical chemistry. Its object is the quantitative determination in the shortest possible time of the products of mining and metallurgical operations. Its scope is limited to those components of a substance which impart to it a commercial value.

Assays may be made by the dry method (furnace assay), or by the usual methods of analytical chemistry. These notes refer solely to the furnace assay of mineral substances containing, or supposed to contain, lead, silver, and gold.

SAMPLING.

It is absolutely necessary that the small quantity of pulp with which the assay is made should exactly represent the average composition of the ore heap, etc., from which it is taken. The manner of taking a sample will vary in different localities and with the material to be sampled. Sometimes the assayer must take, or direct the taking of, the sample for assay. Frequently a small quantity is brought to him either as pulp (*i. e.*, powder) or in pieces varying in size and richness. Suppose a sample of four pounds be handed to him. This should be crushed to pass a 12 to 16 mesh sieve (16 openings to linear inch), taking care that the whole of the sample is crushed. The siftings are now thoroughly mixed (best on an iron plate or rubber cloth) by making them in the form of a cone; flatten cone, and beginning in the centre, draw off the siftings to form a ring of about three times the diameter of the cone. Now begin on the outside of the ring of ore and shovel round and round the circle, dumping the material into the centre, forming a second cone. Flatten this and form a second ring, then a third cone until the material is thoroughly mixed. When an ore consists of several minerals varying in hardness and specific gravity, during the crushing, the softer and more brittle minerals pass the sieve first, and at least three to four shovelings over are necessary to render the siftings homogeneous. The cone is now flattened, and two diameters are drawn at right angles to each other across it. The opposite quadrants are shoveled away and the space brushed clean; the two remaining quadrants are shoveled to a cone, flattened, and the two alternate quadrants shov-

eled away, and this process is repeated until sufficient remains to fill a four or eight ounce bottle. This is crushed or ground to pass a 60, 80, 100 or 120 mesh sieve. The finer the grinding the more dependence you can place on the portions weighed out for assay. Before placing sample in the bottle it must be well mixed, as already explained, and when weighing portions for assay a considerable part of it should be spread on glazed paper, and by means of a spatula small quantities taken from many parts of the surface to make up the portion weighed for assay. If the sample be received in the form of pulp it must be sifted, and any parts remaining on sieve, ground to pass through. If metallic particles of gold or silver, etc., remain on the sieve they must be collected and assayed separately, the weight of the pulp from which they were derived serving as the basis for calculating their value.

The assayer has frequently the sampling of large lots of ore to superintend. As delivered at the mill, or smelting works, it consists of small and large pieces, varying greatly in value and composition. The sampling may be done as follows: The whole lot is passed through a rock-breaker to 2″ cubes or less, and as the heap underneath is shoveled aside, about every tenth shovelful is put in a separate heap. This is crushed fine and quartered, as above described, until perhaps 200 lbs. remain; this is crushed again to pass a $\frac{1}{4}$ mesh sieve, and quartered until about 25 lbs. remain. This is again crushed to pass, say a 16 mesh, and proceeded with, as described, until the desired size and fineness is reached. If the material is damp the crushing is stopped at some convenient stage, the portion weighed, dried, and the loss in weight (moisture) deducted from the weight of ore. This loss will vary from 3 to 15 per cent as ore is delivered from the mines.

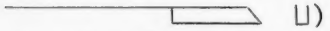
The coarse crushing is usually done by rock-breakers and rolls; the fine crushing by mortars, rubbing-plates, or by sampling machines designed especially for it.

At sampling works several small bottles are filled with the final sample, and each bidder for the ore receives one; the owner of the ore and the sampling works retaining a sample in all cases.

At works where much sampling is done they have some automatic arrangement for taking the sample at the breaker and rolls, so as to avoid the time and expense of hand labor.

Where the material received is fine, as, for instance, the concentrated sulphurets from gold mills, it may be sampled by shoveling, from one heap to another, a portion of each shovelful being caught on a sampling scoop or shovel and dumped in a separate pile. This sample is quartered and prepared as usual. (A form of scoop in use at the Boston

and Colorado Works consists of a sheet-iron trough, perhaps 15 inches in length, with a rectangular section about 2″ wide and 3″ deep and fastened to a handle six feet long.



In dry-crushing silver mills the sample for assay is usually taken as the ore passes from the stamps or rolls to the furnace, either automatically or at intervals of 15 or 30 minutes, the moisture having been previously determined.

In wet-crushing silver mills the ore sample is taken either at the rock-breaker, as described, or more often as the crushed ore and water is flowing into the settling tanks. A common method is to take a dipper or bowl and fill to a certain height at regular intervals of 15 to 30 minutes, emptying bowl immediately into a tub or large vessel where it can settle. After standing, the clear water is poured off, the sample dried and assayed. Never allow bowl to overflow, or concentration will take place. Pass the bowl clear across the falling steam.

Gold ores, when amalgamated on plates and in the battery, must be sampled at rock-breaker. A tailings sample, however, may be obtained by collecting a bowlful at regular intervals as the pulp leaves the plates.

For sifting samples, care must be taken to have well-made sieves. The box-sieves with block-tin rim and the brass wire cloth soldered all around are recommended. Nine inches in diameter is a convenient size. Sieves with wooden rims are objectionable on account of pellets sometimes sticking between the rim and the screen.

BALANCES AND WEIGHTS.

At least three balances are required: —

(1) A balance capable of weighing two kilos, and sensitive to a decigram, for weighing ore samples, fluxes, etc.

(2) A pulp balance for weighing out portions of ore for assay, weighing lead buttons, etc. Should weigh up to 200 grams and turn with $\frac{1}{500}$ gram.

(3) A delicate assay balance for the weighing of gold and silver beads. Should be sensitive to $\frac{1}{100}$ milligram.

Four sets of weights are required: —

(1) 1 kilo to 1 gram, for ore samples, fluxes, etc.

(2) 20 grams to 1 centigram, for weighing portions of ore for assay, lead buttons, etc.

(3) A set of assay ton weights, 4 A. T. to $\frac{1}{20}$ A. T.

(4) 1 gram to $\frac{1}{10}$ milligram, with riders for the assay balance.

The assay ton weights suggested by Prof. Chandler of the Columbia School of Mines are in quite general use, and greatly simplify the calculation of results. They are based on the number of troy ounces contained in one ton of 2,000 lbs. avoirdupois.

Thus the assay ton equals 29.166 grams (29,166 m. g.).

1 lb. avoir.= 7,000 grains, troy.

1 ton = 2,000 lbs.= 14,000,000 grains, troy.

1 troy oz.= 480 grains, hence $\frac{14000000}{480} = 29{,}166$ troy ounces in 2,000 lbs. avoir.

Therefore, 2,000 lbs. : 1 A. T. : : 1 oz. troy : 1 m. g.

If, for instance, 1 A. T. yield 1 m. g. of Au or Ag, the result is one oz. troy Au or Ag per 2,000 lbs. ore. If $\frac{1}{10}$ A. T. be taken, then $\frac{1}{10}$ m. g. means one oz. In the U. S. assays of Au or Ag are always reported in ounces and decimals of an ounce, and lead in per cent. In England Au or Ag are reported as ounces, pennyweights and grains per ton. The Germans have a great variety of weights. The assay unit is usually called the centner. Its weight in different localities varies, but it is usually 5 grams.

FURNACES.

Furnaces for assaying may be heated by solid, liquid, or gaseous fuel. The choice of furnace best suited to the work in hand must be left to the judgment of the assayer. Perhaps the most essential thing is the draught. A strong draught is necessary, and this usually depends on the height and size of the flue.

Two kinds of furnaces are commonly used, the crucible and the muffle. The former is usually rectangular, lined with fire-brick and cased with sheet-iron or common brick. The cover is either of iron or fire-brick tile. A convenient size is nine to twelve inches internal diameter, and fourteen inches from grate-bars to top. They may be made circular in section if desired, and enlarged if necessary. Fuel used is usually coke, anthracite, or charcoal. A muffle furnace consists essentially of a semi-cylindrical oven of fine clay, termed a muffle, supported in a furnace. The muffle is heated from without by glowing fuel (charcoal, coke, etc.), or by flaming fuel (bituminous coal). A great variety is found in the market. The clay furnaces made by the Battersea Co., are good where charcoal is the fuel used. The cracks which usually appear on a first heating are of no especial consequence. There are several varieties of sheet-iron furnaces, lined with fire-brick, using coke, anthracite, or charcoal fuel. If the assayer has much work to do, it is better to build a furnace of fire-brick with sheet-iron casing, taking care that no iron is directly ex-

posed to the heat of the furnace. Glowing fuels require the least attention, but with flaming fuels a more even heat can be maintained; the fire is always under control, and the life of the muffle is much longer. Petroleum and gas furnaces possess the advantage of cleanliness, and the temperature can be very perfectly regulated. They are especially useful in the chemical laboratory where occasional assays are made. Both muffle and crucible furnaces can be bought, adapted for natural draught or requiring blast.

FURNACE IMPLEMENTS.

The tools and implements usually required about the furnace are pokers (straight and crooked), shovel, tongs for handling crucibles, scorifyers,cupels and buttons, muffle scraper, stirring rods (used when roasting ores), pouring moulds, hammers for breaking fuel and removing slag from buttons, an anvil, and frequently other implements for carrying a number of cupels, buttons, etc., etc.

CRUCIBLES AND SCORIFYERS.

The most common brands in the market are the Battersea, Hessian, French, Denver, and Graphite. The Battersea, or London clay crucibles, are satisfactory, on account of their refractory nature and comparative low cost. The Hessian, or sand crucibles, are serviceable and low-priced. They are somewhat more permeable to fluxes, but make a very satisfactory crucible. The French clay crucibles withstand the action of fluxes and high temperature better than either of the preceding, but on account of their high cost and fragility they are not generally used. The Denver crucibles resemble the Battersea, but are inferior to them. Graphite crucibles are especially useful when metals are to be melted; are composed generally of two to three parts graphite and one part clay.

Crucibles to be perfect should possess the following qualities: (1) Not to break or split when exposed to sudden and great changes of temperature; (2) To be highly infusible; (3) To be only slightly attacked by the fused substances they may contain; and (4) To be impermeable, or nearly so, to liquids. Crucibles may be tested comparatively by fusing litharge in them. This exerts a very corrosive action on them, and also filters through them.

Scorifyers are made of material very similar to that of which crucibles are made, and the Battersea, Freiberg, and French are the three principal kinds. The Freiberg are the most satisfactory.

CUPELS.

Cupels are usually made of the ashes of burnt bones, freed from organic matter, ground and washed. It is better to make them than buy them. The prepared bone-ash can be obtained in bulk, and is mixed with just sufficient water to be damp, but not moist,—just moist enough to retain the impression of the fingers when squeezed in the hand. The bone-ash must not be too coarse, or too fine; too wet, or too dry; nor compressed too much, or too little. A little practice will enable the assayer to hit the right point. If the cupel be too porous or too soft, particles of metal will be absorbed; and also, it is very fragile, and if too compact, the melted litharge will not enter the pores but form a ring about the button, stopping the operation. A little pearl-ash, dilute molasses, or sour beer, mixed with the water used in moistening the bone-ash, will give strength to the cupel. About three sharp blows with a wooden mallet gives the requisite compression. They must be removed from the mould with care, and air-dried for several days, and then baked in the muffle, or heated very slowly previous to use.

ASSAY RE-AGENTS.

According to their action these may be divided into (1) Reducing Agents, (2) Oxidizing Agents, (3) Desulphurizing Agents, (4) Sulphurizing Agents, (5) Fluxes proper.

1. REDUCING AGENTS.

Reducing agents are those which have the power of removing oxygen from those bodies with which it may be combined. The common reducing agents are: —

Charcoal.
Argol.
Flour.
Starch.
Sugar.
Cyanide of Potash.
Metallic Iron.

The advantage of carbon consists in its great affinity for oxygen, which at a red heat surpasses that of most other substances. Charcoal by itself is objectionable, on account of its infusibility and inability to combine with fluxes, so that after the reduction is complete the portion

unconsumed is disseminated with the slag and reduced metal, preventing the formation of a good button. A large quantity will irreparably injure an assay. For this reason it is better to use some substance containing carbon, as argol (crude bitartrate of potash, $KC_4H_5O_6$), which yields by decomposition carbon, caustic potash, carburetted hydrogen, and carbonic oxide, the carbon being left in an excessively finely divided state. Flour and starch ($C_6H_{10}O_5$) are used for the same purpose. Potassium cyanide is a powerful reducing, desulphurizing, and fluxing agent. Metallic iron will reduce lead from its oxygen compounds, but is rarely used for that especial purpose. ($Fe + PbO = FeO + Pb$.)

The reducing power of a substance is usually estimated from the quantity of lead yielded by fusing 1 to 2 grams with 60 grams litharge and 20 grams sodium carbonate, and cover of salt. One gram charcoal reduces about 28 grams lead, argol 10–12, flour 10, starch 12, sugar 14.

II. OXIDIZING AGENTS.

Oxidizing agents are those which give up oxygen with facility. The common ones are:—

Litharge.
Nitrates of Potash and Soda.
Ferric Oxide and Binoxide of Manganese.

Litharge, PbO, when melted, oxidizes nearly all the metals except Ag, Au, Hg, etc, and forms fusible compounds with their oxides. If mixed with lead binoxide (PbO_2) it will oxidize silver. The principal use of litharge is for fluxing, desulphurizing, and collecting precious metals.

Action of PbO on

$S + 2\ PbO = 2\ Pb + SO_2$.
$Fe + PbO = FeO + Pb$.
$Zn + PbO = ZnO + Pb$.
$As_2 + 3\ PbO = As_2O_3 + 3\ Pb$.
$Te + 4\ PbO = 3\ Pb + PbO\ TeO_3$ (excess of PbO present).
$2\ Te + 3\ PbO = Te\ Pb_3 + Teo_3$ (when there is no excess of PbO).

Nitrates of Potash and Soda exert a very energetic action because they have a great tendency to suffer decomposition by heat, giving up a large amount of oxygen. This combines with the sulphur contained in the ore, forming sulphurous acid and alkaline sulphates. Also used in purifying noble metals and preparation of some fluxes.

Ferric Oxide and Binoxide of Manganese are reduced to protoxides, leaving an equivalent of oxygen to combine with the sulphur or carbon present.

III. DESULPHURIZING AGENTS.

Desulphurizing agents are those which will remove sulphur from its compounds under the action of heat. The common ones are: —

The Oxygen of the atmosphere.
Charcoal.
Iron.
Litharge.
Alkaline Carbonates.
Potassium Cyanide.
Nitre.

Oxygen. Employed in roasting ores, combining with the sulphur present, forming SO_2 and SO_3, as

$2\ FeS_2 + 11\ O = Fe_2O_3 + 4\ SO_2$, and

$CuS + 4\ O = CuO\ SO_3$.

Charcoal acts on sulphates, decomposing them with evolution of CO_2 and SO_2, and by combining with sulphur to form sulphide of carbon. It acts in this manner with Zns, Hgs, and Pbs. it is not usually employed for its desulphurizing power, but generally for its reducing effect.

Iron separates S from Pb, Ag, Hg, Bi, Zn, Sb and Sn, and partially from Cu. Nails are the most convenient form of iron. Horse-nails or steel-wire nails are the best on account of the small amount of graphite that is left when the metal is dissolved. Iron wire and thin sheet-iron are also used.

Litharge exerts a desulphurizing action on all the metallic sulphides, and if used in sufficient quantity will completely decompose them. The quantity necessary varies, as follows:—

*For	PbS	1.87 parts.
"	FeS	30 "
"	FeS_2	50 "
"	Sb_2S_3	25 "
"	ZnS	25 "
"	CuS	30 "
"	As_2S_3	60 "

The presence of iron and carbon greatly facilitates this decomposition. The following are some of the reactions of PbO on metallic sulphides:

$FeS + 3\ PbO = FeO + SO_2 + 3\ Pb.$

$FeS_2 + 5\ PbO = FeO + 2\ SO_2 + 5\ Pb.$

* Berthier.

$2\ CuS + 5\ PbO = Cu_2O + 2\ SO_2 + 5\ Pb.$
$CuS\ FeS + 6\ PbO = CuO + FeO + 2\ SO_2 + 6\ Pb.$
$Sb_2S_3 + 9\ PbO = Sb_2O_3 + 3\ SO_2 + 9\ Pb.$
$ZnS + 3\ PbO = ZnO + SO_2 + 3\ Pb.$
$PbS + 2\ PbO = 3\ Pb + SO_2.$

If insufficient litharge be used, to effect the complete decomposition, a class of oxysulphides are formed, which enter the slag, carrying silver with them, and are not decomposed at a white heat.

Alkaline Carbonates and the caustic alkalies decompose metallic sulphides, but for some sulphides, as CuS, the presence of carbon is necessary. A certain amount of the metallic sulphides present always combines with the alkaline sulphides, and, to decompose this dissolved portion, iron and carbon are necessary.

$7\ PbS + 4\ K_2CO_3 = 4\ Pb + 3\ (K_2PbS_2) + K_2SO_4 + 4\ CO_2$
$3\ (K_2PbS_2) + 3\ Fe = 3\ Pb + 3\ (K_2FeS_2).$

Nitrates Sodium and Potassium have a very powerful action on sulphides; in fact, if the action is not modified by alkaline carbonates explosion may also take place, and particles be thrown out of the crucible. If nitre be present in sufficient excess all the metals except Au and Ag are oxidized, but when employed in proper quantity the sulphur only is oxidized, and the metal (Pb, Cu, Ag) obtained in a state of purity. With the sulphides of iron, arsenic, antimony and zinc, etc., the oxygen of the nitre is divided between the sulphur and the metal.

IV. SULPHURIZING AGENTS.

Sulphurizing agents are usually sulphur or iron pyrites. These are rarely employed in assaying, but are useful in separating metals and alloys, as Ag and Fe, or Pb and Cu.

V. FLUXES.

These are used to cause the fusion of a body difficultly fusible, or infusible of itself, and to fuse foreign substances mixed with a metal. In general, acids serve as fluxes for bases, and *vice versa*. The common fluxes are:—

Litharge.
Sodium and Potassium Carbonates.
Borax.
Lead.
Silica or Glass.
Cyanide of Potassium.
Fluor-spar.

Litharge is a most useful flux. It readily combines with silica, forming a very fusible silicate. This resulting silicate of lead is a nearly universal flux, forming easily fusible compounds with nearly all the bases. It combines least readily with earths and alkaline earths.

Potassium and Sodium Carbonates act as basic fluxes, being decomposed by silica and silicates. CO_2 is given off and silicate of the alkali formed. The presence of charcoal promotes the decomposition. The silicate forms fusible compounds with most of the metallic oxides and earths, and can retain in suspension, without much loss of fluidity, a large proportion of infusible substances.

The carbonates can be used indifferently, but sodium carbonate is preferred, on account of its cheapness and because it does not deliquesce. A mixture of the carbonates is more fusible than either of itself.

The sodium bicarbonate is in general use, because it is readily obtained, is free from sulphates, and is in a very finely divided state. It is the ordinary cooking soda of commerce. The normal carbonate yields more NaO, weight for weight, than the bicarbonate, and is to be preferred on this account. The soda-ash made by the Solvay or ammonia process, on account of its cheapness, fineness, and freedom from sulphates, is recommended.

Instead of using mixtures of the carbonates and reducing agents, "White" and "Black Flux" are sometimes used. White flux is produced by deflagrating together equal parts of saltpetre and argol; black flux, by deflagrating one part nitre with two to three or more parts argol. The nitre and argol are ground together, and thrown, a little at a time, into a red-hot crucible. Tartaric acid and various empyreumatic volatile matters are given off, and carbonate of soda, or potash, very intimately mixed with carbon is obtained. In white flux the nitre is usually sufficient to oxidize all the carbon. In black flux, the carbon does not hinder the fusing of the assay, and herein lies its advantage. It is used in the lead assay principally. Its action is fusing, reducing and desulphurizing. "Raw Flux" is the above mixture before deflagrating, and "Black Flux Substitute" is a mixture of about 10 parts carbonate of soda and one to three of flour, or a mixture of alkaline carbonate and lampblack.

Borax ($Na_2B_4O_7 + 10\ H_2O$) contains 47 per cent water, and should be heated and water expelled before using. Is an excellent and universal flux. It forms very fusible compounds with silica and all the bases, both metallic and earthy, and can be used at low or high temperatures. It is neither oxidizing nor desulphurizing in its action. It gives great liquidity to slags.

Lead is used in granulated form and as sheet-lead. It dissolves the precious and easily reducible metals and fluxes and desulphurizes the impurities by means of the litharge formed from exposure to the air. Granulated lead is prepared from ordinary refined lead, taking care to select bars containing little silver (less than one oz. per ton, avoir.). Melt and pour five to twenty lbs. into a tight wooden box, roll back and forth until the lead becomes pasty; now shake violently until lead is too cool to agglutinate. Sift through a 16 mesh sieve. A suspended pail or wooden bowl can be substituted for the box if preferred. A very pretty and satisfactory method of making granulated lead is to use a jet of steam to atomize a thin falling stream of melted lead, and receive the granulated lead in a large box or cask.

Silica or Glass combines with all the bases to form compounds more or less fusible. Used when the bases are in excess. Glass is more fusible and oftener used.

Fluor-spar is an excellent flux for baryta *i. e.* (heavy spar.)

SALT.

Neutral in action. Used as a cover, to preserve substances from the action of the air, and to moderate the action of bodies that cause much ebulition. Also, to prevent globules of lead from floating on the surface of the slag.

EXPERIMENTS ON THE BLAKE CONTACT.

BY GEORGE W. PATTERSON, JR., A.B., S.B.

Read at a meeting of the American Academy of Arts and Sciences, Jan. 11, 1888.

IN the spring of 1887, Mr. H. J. Tucker and I experimented on the contact in the Blake microphone transmitter, with the object of determining, if possible, the relation between the normal pressure at the contact, and the current in the receiver of the telephone, which was placed in the secondary circuit of an induction coil in the usual manner.

In the following pages I shall give a brief description of our apparatus, and some account of our experiments, with the results reached; and in conclusion I shall deduce, from a consideration of the apparatus and the laws of electricity, equations for curves of pressure and current, which are similar to those obtained in experiment.

In our laboratory work we had the advantage of a knowledge of the work which had been done in the preceding two years by Messrs. Page, Lewis, and Hopkins, under the direction of Professor Cross, only a portion of which is published.

The object of our work being to determine the variations in the secondary undulatory current caused by variations in the normal pressure at the microphone contact, we required some simple way of regulating the contact pressure,— some way, if possible, which would admit of reproducing the same results from the same conditions of pressure and sound. This latter we failed to accomplish satisfactorily.

Having removed the door, including the microphone contact and the mouthpiece, from the transmitter, we fastened it to the table, leaving space between it and the table for an organ pipe (512 complete vibrations per second), which we used as our source of sound.

To obtain a sound of constant intensity we blew the pipe by means of an air blast driven by the engine in the Rogers Building. The air was regulated by two pressure regulators, one allowing part of the air to escape, the other balancing the air pressure by a column of mercury. The height of the mercury could be changed at will.

The pressure in the Blake contact is regulated by the attachment of the carbon electrode to a spring, whose tension is adjusted by a screw. In addition to the spring, which we used for preliminary adjustment, we applied pressure by means of a lever arm carrying a scale-pan at its centre, one end of which rested on the electrode, the other carrying a knife-edge resting on glass, acted as a fulcrum. The scale-pan was covered by a piece of velvet, in order that the addition of weights might cause no jar at the contact. In our experiments we found that any attempt to take off weights had the effect of disturbing the adjustment of the contact to such an extent as to change the series. This same result was frequently brought about by the jarring of the ground from the street traffic.

We used a more powerful induction coil than that in the Blake transmitter. The resistance of its primary was 0.5 ohms, and of its secondary, 899.0 ohms.

We experimented on various forms of battery with varying arrangements of the cells, to observe the effect of changes in electro-motive force and in resistance. The currents to be measured were very small, and consequently some extremely sensitive form of electro-dynamometer was required. We used one of the Kohlrausch pattern with movable coils, which we wound of No. 40 (B. & S. gauge) double silk-covered wire. The two outer coils might be used either in parallel or in series with each other, and in either way with the inner (suspended) coil.

This dynamometer, which differed in some of its details from the instrument as ordinarily made by Hartmann, was constructed especially for experiments of this nature by Mr. Otto Scholl, the mechanician of the laboratory.

The condition of maximum sensitiveness with coils of a given size, is obtained by arranging them so that the product of the ampère-turns in the outer and the inner coils is a maximum.

In designing our inner coil, we were limited by the size of the tube in which it turned. This coil we wound with as many turns as possible, giving a resistance of 180 ohms, which was not too large for the best conditions, the resistance of the induction coil being high. We then wound two outer coils, each of 800 ohms resistance, which were as large as it was convenient to fit on to the dynamometer.

For maximum sensitiveness, the resistance of the outer coils should be equal to one-fourth of the resistance in circuit. The sensitiveness falls off much more rapidly with decrease of resistance below this point, than it does by increase of resistance above this point. The law being represented by the equation, $Y = \frac{X}{(\alpha + \beta X^2)^2}$ in which Y is a measure of the sensitiveness, X the resistance per foot of the wire in terms of the resistance per foot of the wire of the standard coil, β the total resistance of the standard coil, and α all other resistance in circuit, about 1,100 ohms. βX^2 is the resistance of the outer coil, the resistance of a fixed weight of wire being inversely as the square of its resistance per foot. Y is a maximum when $\alpha = \frac{1}{3} \beta X^2$.

It will be seen from the above equation that if the outer coils are used in series, the resistance, 1600 ohms, is much too large; if they are used in parallel, the resistance, 400 ohms, is also large; and the instrument is 64 per cent more sensitive with the parallel arrangement. For best effect, the wire of the outer coils should have had a section 91 per cent larger, and the coils should have been used in series, or a section 4 per cent larger, and have been used in parallel. However, we found that if the outer coils were used in parallel, the dynamometer was sufficiently sensitive.

For a suspension, we finally used a platinum wire, 0.004″ in diameter, all lighter ones breaking, because of the weight of the coil. The length of the wire was about twenty inches. The inner coil carried a vane, swinging in dilute sulphuric acid, by which one connection was made, the other being made by means of the suspending wire. Mercury was not used, as its surface tension would not allow free enough motion of the contact wire. The deflection of the inner coil was read by a telescope and scale, a mirror being fixed to the coil.

As the currents to be measured were alternating, it was necessary to calibrate the electro-dynamometer for alternating currents; for in rapidly alternating currents the inner coil is acted on by the outer coils only, while in direct currents the magnetism of the earth is felt also. In 1886,

Mr. Hopkins inserted a current alternator between the battery and his dynamometer, but found a great deal of trouble from leakage across the insulation. We therefore sought to calibrate the dynamometer with direct currents, and, by a mathematical consideration of the curve obtained, to construct a curve proper for alternating currents.

In calibrating this dynamometer we met with considerable difficulty, for it was far too sensitive to be put in direct circuit with the most sensitive standard galvanometer, and it could not be placed in a shunt circuit, because of the impossibility of determining its equivalent resistance, the inverse electro-motive force of the sulphuric acid contact entering in as a doubtful element.

These difficulties were overcome by setting up the dynamometer with the planes of its outer coils east and west, connecting it in series with a very sensitive bell-magnet galvanometer, and observing the corresponding deflections. Series were taken by varying the resistance in circuit, and also reversing the current both at the battery and in the inner coil. The bell-magnet galvanometer having been calibrated by a standard instrument, we computed the currents* corresponding to the different deflections, and plotted the curves of deflection and current for the dynamometer. These curves were found to be two equal parabolas, whose equations were $C^2 - 1.297\,C = -.134\,S$, (1) and $C^2 - 1.297\,C = .134\,S$ (2), C being the current in milliamperes and S the scale readings in millimetres.

Each parabola was constructed from two series of measurements in both of which the relative directions of the current in the outer and inner coils were unchanged, each series being represented by a branch of the parabola.

It was next necessary to find the law which the dynamometer would follow for alternating currents.

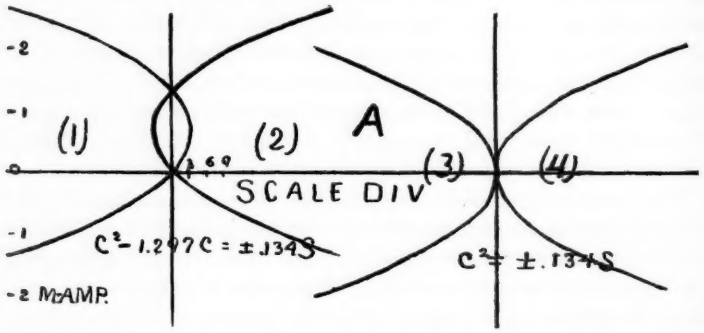
Taking the forces acting along any line passing through the centre of the coil, we have for the action between the coils a force proportional to the square of the current, and for the action of the earth's magnetism on the suspended coil a force proportional to the current. These two forces are balanced by torsion. Expressed in the form of an equation, this gives $\alpha C^2 + \beta C = \gamma$, where C is current and α, β, γ constants for that position. To obtain the same deflection we might have used a negative current, C^1, which may be expressed as $-n\,C$, then $\alpha n^2 C^2 - \beta n C = \gamma$; from these two equations it follows that $\alpha C^2 n = \gamma$, that is, eliminating the earth's action, a steady current of $C\sqrt{n}$ would produce equilibrium in this position. But, as $C\sqrt{n}$ is a mean proportional between the arithmetical values of the two currents which produce equilibrium in this position, we

*A variation of 0.00001 ampère in the current could be measured.

have simply to find the mean proportional for each position, and construct a new curve. Solving equations (1) and (2) we get

$$C = \frac{1.297}{2} \pm \sqrt{\left(\frac{1.297}{2}\right)^2 \pm .134\,S}.$$

A mean proportional between the values of C for (1) is $-.134\,S$; for (2) it is $+.134\,S$. Therefore, the equations for a direct current when the inner coil is free from the earth's effect, are $C^2 = -.134\,S$ (3) and $C^2 = +.134\,S$ (4). In the case of an alternating current we have a continuous variation in strength; but if we understand by C^2 the mean value of the square of the current, and not the square of its (arithmetically) mean value, which is nearly 20 per cent smaller, when the current variations are of a simple harmonic character, we may use equations (3) and (4) to express variations of current and deflection for alternating currents. In changing from (1) and (2) to (3) and (4) we have made a change in the axes only, the curves being identical.



It will be seen from the demonstration that this transformation of axes without change in the form of curve is peculiar to the parabola.

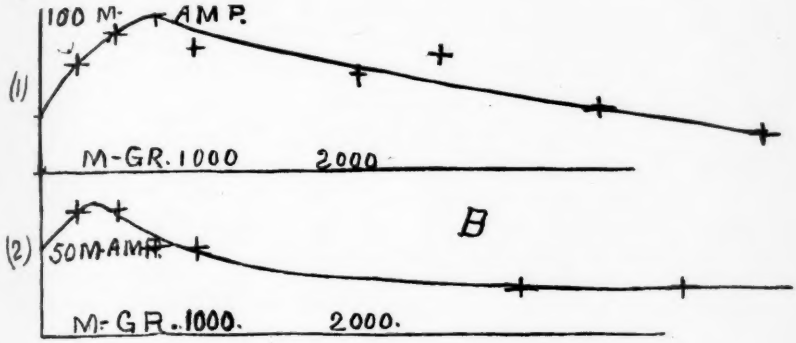
The calibration being completed, we proceeded to investigate the law of pressure and current, using the Dolbear and chromic acid primary batteries and the Brush storage battery.

The pressure at the contact was adjusted by the spring until the addition of 25 m.gr. would allow sound to be transmitted through the telephone; the weight was then increased, at first by additions of 250 or 500 m.gr., and afterward more rapidly.* The deflections, the quality, and the intensity of the sound transmitted, were noted. The following plots and tables will serve as examples of the series.

The values given on those of the steady currents which, in the absence of any magnetic effects from the earth, would give the deflections observed.

* In some series the increment was only 25 m.gr.

As the precise form of the variation of the current is uncertain, no better mode of procedure has suggested itself. The columns headed Def., C., Wt., etc., contain the observed deflections, the calculated currents, and the weights in the pan. These weights should be devided by 2 to obtain the pressure at the contact.



BRUSH STORAGE BATTERY, TWO CELLS IN PARALLEL.

(1)				(2)			
Def.	C.	Wt.	Remarks.	Def.	C.	Wt.	Remarks.
.85	.34	0	Broken sound.	2.20	.54	0	Roaring.
3.05	.64	250		4.05	.74	250	Bad.
5.30	.84	500	Loud, and beginning to be musical.	4.30	.76	500	
6.45	.93	750	Loud and good.	2.10	.53	750	Loud, and beginning to be good.
4.35	.76	1,000	Lower, and clear.	2.05	.52	1,000	
3.95	.73	1,500	Wavy.	.65	.29	3,000	Loud and good.
2.55	.59	2,000	Good.	.65	.29	4,000	Good, but growing fainter.
1.75	.68	2,500		.45	.25	5,000	
1.10	.39	3,500	Low.				
.32	.20	4,500	Very low.				

It will be noticed that the current rises very rapidly at first with this increase of pressure. At all points of this rapid rise the sound transmitted is very bad, and there are very frequent breaks with the intensity of sound employed. The maximum is soon reached, at about 1000 m.gr. pressure, and from that point the current falls off gradually. The sound

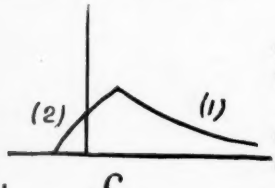
becomes good soon after the maximum current is reached, and as the pressure increases, the sound diminishes in intensity, but improves in quality. In all our experiments the same form of curve represented the variation of pressure and current, and in all, the best sound was transmitted directly after the maximum current.

I find that this form of curve is in harmony with theory, assuming that the pressure at a microphone contact varies inversely as its resistance. The total resistance in the circuit is a constant plus the resistance of the joint. This may be expressed by the equation $R = \alpha + \frac{\beta}{P}$, R meaning resistance, P pressure, and α and β constants. But, $C = \frac{\gamma}{R}$ C meaning current and γ a constant; therefore $C = \frac{\gamma P}{\alpha P + \beta}$. Suppose the sound waves due to the pipe to cause a varying pressure on the contact, whose extreme values are $\pm \delta$. The extreme values of the resulting current will be in each vibration $\frac{\gamma (P+\delta)}{\alpha (P+\delta)+\beta}$ and $\frac{\gamma (P-\delta)}{\alpha (P-\delta)+\beta}$. The difference between them will be proportional to the secondary current I. The secondary current depends on the rate of change in the primary. This relation may be expressed by the equation

$$I = \Theta\left[\frac{P+\delta}{\alpha(P+\delta)+\beta} - \frac{P-\delta}{\alpha(P-\delta)+\beta}\right] = \frac{2\beta\delta\Theta}{\alpha^2(P^2-\delta^2)+2\alpha\beta P+\beta^2}, \quad (1)$$

If P is less than δ, it is evident that the electrodes will break contact, a minus pressure being impossible. In this case the current at one extreme will be 0 instead of $\frac{\gamma(P-\delta)}{\alpha(P-\delta)+\beta}$, and the secondary current I will be $\frac{\Theta(P+\delta)}{\alpha(P+\delta)+\beta}$, (2)

When $P = \delta$, these two values for I are identical. The curve, obtained by following (2) up to the point $P = \delta$, and (1) after that, is similar to the accompanying sketch (C).



C

The similarity between the curves B and the curve C shows the close agreement of theory with the results observed.

The first part of the curve, corresponding to equation (2) of incomplete contact, is the curve of imperfect transmission; the last part of the curve, corresponding to equation (1) of complete contact, is the curve of good transmission.

From equations (1) and (2) it will be noticed that the pressure required for good transmission of sound is dependent on the intensity of the sound, good sound being transmitted if δ is less than P. The sound in the receiver is loudest when δ is nearly equal to P.

In experimenting with electro-motive force greater than 3 volts, we met with unsatisfactory results. Good sound was not transmitted except under heavy pressure, and all attempts to obtain satisfactory measurements failed on account of the well-known disturbances set up in the microphone by the current itself.

In certain of our experiments the resistance of the primary circuit was diminished by joining a number of cells in parallel. The uniform result was that the sound transmitted was louder.

The results of our experiments may be summed up as follows: —

The resistance of the primary circuit and especially that of the battery should be as low as possible; the pressure at the contact should be no greater than is required to transmit good sound,—that is, it should be a little greater than that required to give the maximum current; with the present form of Blake contact, no electro-motive force greater than 2 volts should be used; and, finally, the contact should be carefully guarded against jarring.

Our work should be considered not as a complete investigation, but as part of the foundation for future work in the Rogers' Laboratory; for our results have been more in the invention of methods than in the use of them. We trust that the work in which we have had a share may be successfully carried out in the future.

Rogers Laboratory of Physics, January, 1888.

ON THE JOINT STRUCTURE OF ROCKS.

BY W. O. CROSBY, S.B.

FIVE years ago[1] I proposed to recognize three classes of joints, as follows: (1) The parallel and intersecting joints, which are found in all rocks, but are especially characteristic of stratified formations. (2) The non-parallel and non-intersecting joints observed chiefly in eruptive rocks and having their best development in the columnar jointing of the basaltic rocks. (3) The comparatively unimportant joints parallel with the surface, so clearly exposed in many granite quarries, and rarely observed except in very massive, granitoid rocks.

[1] Proc. Boston Soc. Nat. Hist., vol. XXII., pp. 72–85.

This third class of joints has been satisfactorily explained as due to expansion, caused by the sun's heat from day to day and from season to season. Hence, in allusion to their origin, these may be very properly called *expansion joints.* The second class, after having been for many years variously explained as a species of crystalline or concretionary structure, is now, by the common consent of geologists, regarded as originating in the contraction of the rocks; the contraction being due chiefly to the cooling of eruptive rocks and the desiccation of sedimentary rocks. These are, therefore, now properly known as *contraction joints,* or *shrinkage cracks.*

The joints of the first class are by far the most universal and important. Many and diverse theories of their origin have been proposed, but geologists finally settled down to the conclusion that shrinkage is the main cause; and this is the explanation given in nearly all the standard text-books of geology, the first and second classes of joints not being distinguished. Mr. Gilbert, however, showed very conclusively nearly six years ago[1] that the parallel and intersecting joints possess none of the characteristics of cracks known to be due to shrinkage, such as are exhibited in desiccated clays, and that from the nature of the case it is impossible that they should. He also pointed out that all other explanations of this class of joints proposed up to that time are equally untenable.

The way thus appeared open for a new explanation of ordinary or parallel jointing; and the principal object of my paper above referred to was to show that the fractures of the earth's crust, generally believed by geologists to result from the vibratory movements known as earthquakes, must be plane, parallel, intersecting, and normally vertical; possessing, apparently, all the characteristics of parallel joints. So far as I can learn, no serious or unanswerable objections to this earthquake theory of parallel jointing have yet been advanced. I desire, however, to re-state my conviction that earthquakes are a principal, but not the sole, cause of parallel jointing. During the plication and displacement of great masses of rocks, tensional and torsional strains must often be developed, which will find relief in parallel fractures.

The main outlines of the earthquake theory were accepted by Mr. Gilbert[2], but he also called attention to some minor peculiarities of this class of joints which were not satisfactorily accounted for in my first paper, especially to the fact that while, as a rule, the angle of intersection of the systems of joints is large, it is occasionally very small. In

[1] Amer. Jour. Sci., vol. XXIV., 1882, p. 50.

[2] Amer. Jour. Sci., vol. XXVII., 1884, pp. 47–49.

a second contribution[1] to this subject, however, I endeavored to show that these facts may be harmonized with the theory, if we make the not unreasonable assumption that while oblique earthquake vibrations of low velocity would be relieved by slipping along the pre-existing joint planes, oblique vibrations of high velocity would be so nearly instantaneous as to produce fractures normal to their direction before the inertia of the rock in the direction of the pre-existing joints could be overcome. This second paper also embodies an account of the remarkably perfect parallel jointing of the Miocene clays and sands forming the Nomini Cliffs, on the Potomac River, in Virginia, and of the columnar jointing of the felsite in Needham, Mass. The former example is shown to be in perfect agreement with the earthquake theory, and to be entirely inexplicable by any other hypothesis.

During the two years since these notes were published, additional confirmations of the theory that parallel and intersecting joints have been produced by movements, and chiefly by vibratory movements, of the earth's crust, have come under my observation, and my present purpose is to describe the most striking of these.

The celebrated section of the Carboniferous formation on the South Joggins Shore, in Nova Scotia, embraces in a nearly continuous exposure about 15,000 feet of strata. Although the geological interest of this unparalleled section centres in the numerous beds of coal with their under-clays penetrated by Stigmaria roots and their roof-shales crowded with ferns, still, this immense thickness of strata is made up mainly of beds of sandstone, and of grayish, greenish, and reddish shales, the shales predominating. The beds vary greatly in thickness, but the sandstone layers, at least, rarely exceed twenty feet, and the entire section, omitting the coal-seams with their under-clays and roof-shales, presents a constant alternation of sandstone and shale in comparatively thin beds. The dip of the strata is southerly, remarkably constant, and so low (averaging nineteen degrees), that at almost any point along the cliffs a vertical line would cross the exposed edges of several beds of sandstone and the intervening beds of shale.

The sandstone beds are traversed at most points by at least two systems of well-developed and remarkably regular parallel joints. The joints, like the fossil trees which are such an interesting geological feature of this shore, are normal to the bedding, and usually terminate abruptly at the borders of the sandstone, being rarely traceable into or through the shale. But the shale is, for the most part, in a finely comminuted or chaotic state, *i. e.*, essentially structureless, so far as any

[1] Proc. Boston Soc. Nat. Hist., vol. XXIII., pp. 243–248.

regular or recognizable jointing is concerned. Furthermore, it seems extremely doubtful if the shale has ever possessed a joint structure similar to, or coincident with, that of the sandstone. For if the jointing of this formation be attributed to shrinkage, it is necessary to suppose, since the two rocks must vary greatly in their co-efficients of contraction, that the clay or shale beds would be much more finely divided by this cause than the sandstones. And if the earthquake theory of the jointing be accepted, it is equally clear that the shales, being naturally more inelastic than the hard and rigid sandstones, as well as more fissile and interrupted in structure, would offer greater resistance to the passage of the earth-waves, and consequently be more frequently broken by them. Hence it is evident that, since both theories of jointing consist with the marked structural contrast presented by the shales and sandstones, this contrast cannot be said to add weight to either hypothesis.

The fact of special significance, however, so far as the origin of the jointing of these rocks is concerned, is that while the beds of sandstone are so strongly contrasted in their jointing with the intervening shales, they are in perfect agreement in this respect with each other. At almost any point along the cliffs, where several beds of sandstone can be seen one above another, an almost absolute correspondence in the joint structure of the successive beds is very evident. In most cases, two systems of joints intersecting approximately at right angles are well developed; and in following the joints down from one bed of sandstone to the next, they are usually found, although completely interrupted by the shale, to coincide exactly in position and direction. Along a considerable part of the Joggins section, which I have particularly examined, neither system of joints coincides with the trend of the shore. Consequently, the edge of each bed of sandstone, as it is exposed in the face of the vertical cliff, is distinctly notched, like the edge of a saw, the sharply defined notches varying in width from a few feet to a few yards. Each bed of sandstone thus exhibits on a small scale the jogging which gives the entire shore one of its most distinctive features and its name. The serration of the beds of sandstone is not only of interest as tending to show how erosion has here been influenced by the regular joint structure, but also because it makes the correspondence in the jointing of the successive beds of sandstone much more conspicuous than it otherwise would be. It is usually evident to the most casual observation that each bed of sandstone agrees exactly in its serration, *i. e.*, in the form, size, and position of the notches, with the beds above and below it in the same vertical section.

Now, granting, merely for the sake of the argument, that shrinkage might give rise to the very typical parallel and intersecting jointing of the sandstone, it must still, I think, be conceded that earthquake vibrations afford a much more natural explanation of the close correspondence between the joints of the different beds. Earth waves of such large radius as to have sensibly parallel lines of propagation ought, if the sandstone is fairly homogeneous, to affect adjacent beds in a similar manner as regards not only the direction, but also the frequency, of the fractures to which they give rise. In other words, the separate beds would be affected essentially as if they were parts of the same bed; and the correspondence observed is thus a very natural, and, as regards their directions, a strictly necessary, feature of earthquake fractures. Shrinkage, on the other hand, would naturally act independently in the different beds of sandstone; and no reasons are apparent why the shrinkage cracks in successive layers should coincide either in position or direction.

One general fact which may be observed in many localities, but which particularly attracted my attention on the Joggins Shore, has not heretofore received adequate emphasis as an argument against the shrinkage theory of parallel jointing. The joints of this class are usually and normally mere fractures, with the opposing walls in close contact; while joints known to be due to shrinkage, such as the cracks in desiccated clay, are usually fissures of sensible, and often of considerable width. A fine illustration among the older formations is afforded by the purple limestone of the Black Hills, in Dakota. This formation, which has been referred by different authors to both the Triassic and Carboniferous systems, has an average thickness of only twenty-five feet, and is thus described by Newton[1]:—

"The purple limestone is very conspicuous in the geological structure of the Black Hills, and an important element in the topography. It forms the outer slope of the main portion of the Hills, and in a sloping belt from half a mile to three or four miles in width, dipping outward from 20° to 30°, completely encircles them. It preserves the underlying red clay and sandstone from denudation, and defines the inner margin of the great encircling Red Valley. It is so much harder than the overlying clay, and lies at so steep an angle, that it is swept clean, not only of the clay, but of all soil, and forms a bare and slippery pavement of rock, which, by its seams and peculiar weathering, has acquired a tesselated appearance. Were it not for the breaks caused by the cutting of the cañons of the outgoing drainage, one could drive many wagons abreast

[1] U. S. Geol. Survey, Report on the Geology and Resources of the Black Hills of Dakota, 1880, p. 132.

entirely around the Hills on this encircling limestone pavement." Over many hundreds of acres the surface of the limestone conforms exactly with the bedding, every curve and undulation of the strata being faithfully indicated in the superficial contours.

The limestone is grayish, pink, or purple in color, devoid of organic remains, and highly argillaceous. It is, in fact, a consolidated calcareous mud, and was probably deposited in very shallow water. The tesselated appearance to which Newton refers, and which, on account of the general absence of soil from this formation, is exhibited continuously over acres of surface, is plainly not the result of weathering; but it is an original structure due to shrinkage. The surface of the limestone is usually divided, after the manner of desiccated clays, into polygonal blocks from a few inches to a foot or two in diameter. The bounding cracks are commonly from one-eighth to one-half of an inch in width at the top, but usually become rapidly narrower downward. This narrowing is due to a very characteristic feature of typical shrinkage cracks, which is exceptionally well devoloped here, viz., the concave curvature of the upper surface of the blocks. It is a familiar fact that in desiccated clays the individual polygonal blocks are distinctly concave, or saucer-shaped, owing to the circumstance that the surface of each block dries and contracts more rapidly and thoroughly than the lower portion, the upper layer of clay warping, or rolling up at the edges, like a sheet of drying paper. This is exactly the structure of the purple limestone; and we may conceive it to have been deposited in a very broad and shallow lake or sea which, like the playa lakes of the Great Basin, was subject to periodic desiccation.

---

*THE ODOR AND COLOR OF SURFACE WATERS.**

BY THOMAS M. DROWN, M.D.

IT may be said, in a general way, that river, lake, and pond waters have more or less odor and color, and contain generally some solid suspended matter. It is not often, except in mountainous regions, that we meet with clear, colorless, and odorless surface waters.

By the association of these characters of odor and color I do not intend to suggest that there is any intimate or uniform relation between them. Indeed, one may say that the odor gives very little suggestion

*A paper read before the New England Water Works Association at the meeting in Boston, Dec. 14, 1887.

as to the color, and that the color will not enable us to predict the odor. The subjects are, nevertheless, conveniently treated together as they are characters which appeal to the senses of the ordinary observer, and can be determined without the use of special apparatus and reagents. Any one with a good eye for color and a good nose for odor can correctly characterize a water in these regards, and can draw important conclusions as to the origin and nature of the water.

I. ODOR OF SURFACE WATERS.

What we call the odor of a solid or liquid is the effect produced on the nerves of smell of the gaseous emanations from the solid or liquid. If this gas or vapor is given off freely, or is particularly intense in its nature, we say the odor is strong or decided. If, on the other hand, the vapor is feeble in its action on the nerves of smell, or is minute in quantity, we say the odor is faint or insignificant. In determining the odor of a water we must distinguish between the odor which is ready formed and that which the water is capable of developing. By odor ready formed, I mean the gases which are dissolved in the water and which can be driven off when the liquid is heated or violently shaken with air ; and by the odor which the water is capable of developing, I mean the gases which may be generated by chemical or other changes in the matters which are held in suspension or in solution.

In a water containing but a small amount of odorous gas, which is given off very slowly at ordinary temperatures, one would fail to detect any odor by smelling a small quantity of the water contained in an open vessel as a dish or tumbler. But if the gas is liberated in a confined space, it may be then recognized without difficulty.

My practice in determining the odor of a water is as follows:— A glass-stopped bottle of about a gallon capacity, when about half full of the water, is shaken violently for a few seconds, the stopper removed, and the nose quickly inserted into the neck of the bottle. For this purpose the bottle must have a very wide mouth ; it is useless to attempt to get the odor by placing the nose at the mouth of a narrow-necked bottle, unless, indeed, the odor is very strong. The foaming of the water caused by the violent shaking with the air in the bottle, liberates some of the dissolved gases, which communicate their odor, if they have any, to the inclosed air in the bottle. Many waters which would ordinarily be classed as odorless give, when treated in this way, distinct odors, and the odors of those waters which are faint under ordinary conditions are very much intensified by this treatment.

In using this method it must be borne in mind that the amount of gas which can be liberated in this way is generally very small, and may be exhausted in one or two shakings. The odor is always stronger after the first shaking, and often becomes imperceptible after repeated trials.

The odor thus obtained is from the dissolved gases which are the result of changes which solid matters of some kind have previously undergone. Now, if the water in which the odorous gases were contained was free from dissolved or suspended matters, it would remain odorless when once these gases were driven out. But such a condition of affairs rarely exists in surface waters; they generally contain both dissolved and suspended organic matters which change more or less rapidly, and develop, as the result of this change, fresh quantities of gas. Hence, after the odor of a water has been exhausted by shaking, it may be detected again, after the lapse of some hours, by the same operation. Thus we distinguish, naturally, between the odorous gases which are present in a water and those which the water is capable of producing.

We have a ready means of learning something about the nature of the dissolved and suspended matters by heating the water and noting the odor which is thereby developed. My practice in this regard is to pour into a beaker-glass, about 5 inches high, a sample of water so that it shall occupy about one third of its height. The beaker is covered with a watch-glass, and placed on an iron plate which has been previously heated, so that the water shall quickly come to a boil. When the water is in incipient ebullition — not actually boiling — the beaker is removed from the iron plate and allowed to stand until it is cool enough to permit of being smelled without burning the face by the steam. The water in the beaker is then shaken, the watch-glass taken off, and the nose at once put into the beaker. The odor, under these conditions, is generally only perceptible for a second or two. The odors which we note under these conditions are sometimes the same as those noted in the cold, and sometimes they are very different. We must expect the dissolved gases to be driven out of the water by heating even more perfectly than they are by shaking, and we might anticipate, therefore, that the odor obtained on heating would be the original odor intensified. This is sometimes the case, but ordinarily this odor is less pronounced, because the quantity of water on which we operate is very much less than when we get the odor from the bottle. If we should experiment on the same bulk of water in both cases the result might be more instructive, but for many reasons this is scarcely feasible in every-day working in the laboratory.

But the most interesting feature of the examination of the hot water is the development of an entirely new odor, and one which could not have been expected from the odor of the water when cold. Now the source of this "hot odor" when different from the "cold odor," must be in the dissolved or suspended organic matter, and from the character and intensity of this odor we may draw some conclusions as to the nature of this organic matter.

An example or two will make the foregoing clearer. The odor of the Sudbury and Cochituate supply of Boston as drawn from a tap, is, at present, very slight, or even imperceptible if one smells of the water in a tumbler. But when shaken in a bottle, as already described, it gives the characteristic odor which has been the subject of so much comment and investigation in past years. When the water is heated in a covered beaker this odor is much increased in intensity, and remains even when the water is concentrated to half its bulk by boiling. If, however, the water, which contains considerable fine suspended matter, is carefully filtered, no odor (or at most a very slight odor) is developed on heating. In this case it is evident that the source of the intensified odor was in the suspended matter, for on no other supposition can we account for the fact that no odor was developed after filtration. If the suspended matter is precipitated by alumina the action is still more striking, for we then have a clear, colorless, odorless, supernatant liquid and a precipitate which gives the original odor on heating. Jamaica Pond water has at present a distinctly straw-like odor at ordinary temperatures, and a strong grassy and hay-like odor when heated. When the water is filtered and then heated, this grassy odor is entirely absent. On inspection the water is noticed to be decidedly turbid from fine white suspended matter. It seems, therefore, fair to conclude that it is this fine suspended matter which gives the grassy odor on heating. The waters of other ponds which have been investigated in this way, that is, by heating the water both as it comes from the pond and after filtration, have given similar results. The effect of heat on the suspended matter in the unfiltered water may be to vaporize some of their more volatile constituents, perhaps of the nature of essential oils. The odors of this class of waters when heated are peculiar, generally unpleasant, but they do not suggest decay.

When we attempt to describe by name the odors we meet in surface waters we find the task is not altogether an easy one. It is often impossible to get two or more persons to agree as to the precise nature or name of an odor. In this respect I do not know that a chemist is any more qualified to speak with authority than any one who has a good

olfactory organ. Still, with the experience derived from the examination of more than a thousand waters, I have ventured to suggest a series of terms which can be fairly called, I think, characteristic of surface waters by reason of their constant recurrence. These are: "earthy," "straw-like," "mouldy," "wooden," "musty," "disagreeable," and "offensive." Odors which do not come under any of these heads may be specially characterized or included under the general term "peculiar."

These odors are all familiar ones, but perhaps the terms used may not convey the same idea to all. "Earthy," is the odor of freshly-turned soil, or of a moist hot-house; it often passes into "musty." "Straw-like" is the odor of moist straw; I think no one could mistake it or fail to recognize it; it is one of the most frequent odors met with in surface waters. "Mouldy" is the odor of moist straw which has begun to decompose; there is nothing disagreeable suggested by it; it is also somewhat allied to the earthy or loamy odor. "Mustiness" is advanced mouldiness, and verges on the disagreeable; it is the odor of damp, closed vaults. "Wooden" is the odor of tubs with hot water; it suggests wash-day. "Disagreeable" is a more difficult term to explain, first, because it is not easy to get agreement among different observers on this point, and secondly because under it we include two classes of odors, namely, those of growth and those of decay. Some aquatic plants and low animal organisms give off mal-odorous gases as the product of their normal growth, and all organisms are more or less mal-odorous in the process of decay. Now it sometimes happens that these two odors cannot be sharply distinguished from one another; they are both unpleasant odors. So in the absence of finer discrimination of odors, or the positive identification of the noxious plants or animals, there seems to be no other way than to include them under the head of "disagreeable." It is of interest to note in this connection that river waters rarely give, either cold or hot, these "disagreeable" odors. They are generally confined to the waters of lakes, ponds, and reservoirs which have abundant vegetation and but little motion. River waters, even those of considerable organic impurity, give "straw-like" and "mouldy" odors, but the unpleasant, fishy, oily, and rotting odors are, as far as my experience goes, generally absent. "Offensive" is a term sufficiently characteristic; it is more than disagreeable and may be reserved for waters undergoing putrefactive change, or for those which contain considerable sewage. Of the odors of the waters at ordinary temperature, the most frequently recurring are "straw-like," and "mouldy," and "disagreeable." When heated, the "wooden," "earthy," and "musty" odors are apt to be developed.

To express degrees of intensity of odor I am in the habit of using the qualifying terms, — "very faint," "faint," "distinct," "decided," and "strong." A good deal of personal equation comes in here. What is "faint" to one is "distinct" to another and "very faint" to a third. Still there seems to be need for some degrees of comparison of intensity of odors, and, at all events, the use of any set of terms by the same observer will give comparable results.

The origin of the odors of surface waters, when uncontaminated with sewage or other drainage, is clearly referable to the vegetable and peaty matters of the soil over and through which it flows, and to the vegetable or other growths in the water itself.

If we take autumn leaves direct from the trees, so that they can have no possible contamination with earthy matters, clean them, and soak them in water, we give to the water an odor like tea, also a somewhat sweetish odor like syrup. This odor is often quite permanent both cold and hot. After this first odor is extracted from the leaf, subsequent treatments with water extract less and less odor.

When fresh mould or peat (which is formed by the decay of leaves year after year, and contains in addition to matter of vegetable origin the remains of animal life) is treated with water, it gives to the water at first a strong mouldy odor, which, however, is seldom disagreeable. Repeated treatments of this peat with water give, as in the case of leaves, solutions of gradually decreasing odor. The length of contact of the water with a peaty soil, the rate of flow of the stream, the character of the drainage area, whether wooded or barren, uncultivated or in crops, may be mentioned as conditions which have a marked influence on the odor of the water as well as on the color.

The investigation of the odors produced by vegetable growth in water is a subject for the botanist. To what extent these odors are the result of the normal growth of specific plants, or to the result of their disintegration and decay, or of decomposition of vegetable matter in general, I do not care to express an opinion. The systematic examination now being carried on by the Massachusetts State Board of Health into the nature of the water supplies of the State, and the record which has already been made for more than six months of the odors and composition of these waters, will undoubtedly prove useful to the botanist who in the future will undertake the study of this important subject.

II. THE COLOR OF SURFACE WATERS.

When one looks at the large number of samples of water on hand at any one time in the laboratory of the Massachusetts State Board of Health,

which are all from regular sources of supply from different parts of the State, he cannot fail to be impressed, I think, with the fact that comparatively few of them are colorless. The greater part of them are more or less yellowish-brown. Ground waters are, or should be, quite colorless, but river, lake, pond, and brook waters are, as has been already said, very generally colored, and more or less turbid, and have more or less floculent sediment.

The origin of this color is to be sought, as in the case of the odor, in vegetable and peaty matter. We can imitate it in the laboratory very closely by treating leaves and peat with water, as is seen in the example before you. (Samples of water colored by leaves and peat, also samples of river waters were exhibited.) The waters vary much in color from different localities, and at different seasons of the year, but the character and tone of the color is generally the same — a yellowish-brown. Perhaps somewhat more yellow from new vegetable matter, more brown from older vegetable matter and from peat.

It is a matter of great importance to be able to express on some definite scale the intensity of this color, for the purpose of comparison of different waters, and for the comparison of the same water at different seasons and under different conditions. The scale which I have adopted is that formed with varying amounts of ammonia with the Nessler reagent. It is doubtless known to most of the members of this Association that the free and albuminoid ammonia obtained in water analysis is estimated by the color produced by adding the Nessler reagent to the distillate obtained on boiling the water. The intensity of the color is proportionate to the amount of ammonia present, and if we compare the colors thus produced with others obtained by the use of known amounts of ammonia, we arrive directly at an accurate determination of the ammonia in the water.

Now this color is very nearly the same as the color in natural surface waters, and can be used as a scale for recording these colors. There are cases, notably in the deeply-colored waters, where difficulty is met in matching the colors with Nesslerized ammonia, but the difficulty can generally be obviated by using a less depth of the water, or by diluting it with a colorless water. The comparison is made in Nessler tubes precisely in the same way as the colors are matched in the ordinary analysis. The Nessler tubes that I use are about three-quarters inch in diameter and twelve inches long, and the water has height of nine inches in the tube. The numerical scale that I use is as follows: Color No. 1 is that produced by Nesslerizing one cubic centimetre of the standard ammonium chloride solution, which contains 0.00001 gram of ammonia.

Color No. 2 is that produced by two cubic centimetres of this solution, and color 0.1 is that produced by one tenth of a cubic centimetre. In the bottles before you are several examples of colors which have been thus determined, but it must be said that one cannot judge accurately of a color by looking at it in large mass in a bottle. Accurate measurement is best made in the tubes just described.

I cannot give an example of any river or lake water as a permanent standard of color, since all surface waters vary from time to time, but the following examples may serve to illustrate the range of variation in well-known waters. The Sudbury and Cochituate supply of Boston as it flows from the tap in the Institute of Technology, has only varied from 0.5 in August to 0.25 in October. Lake Cochituate has not been higher than 0.3 since last May, but Farm Pond and Beaver Dam Brook have been as high as 1. in this time, and Basin No. 3, Southboro, as high as 1.3, and Basin No. 2 as high as 1.5. Merrimack River at Lowell and Lawrence has varied from .3 to .7, the higher number being observed in November. Taunton River is more highly colored; from July to November its color has varied from 1.1 to 1.8. Brockton's supply from Salisbury Brook is tolerably constant at 1., the range being 0.8 to 1.2. New Bedford water is also uniformly high colored; in July it was 2.2, since which time it has decreased, the record for the last three months being constant at 1.2.

Filtering through paper, except in cases of extreme turbidity, does not often affect the color, and I am accustomed to determine the color in the water as it is collected.

The convenience to the chemist of this system of measuring colors in natural waters is very great, since the materials for matching the colors are always at hand, and, when many water analyses are being made, the standards for comparisons are necessarily prepared for the determination of the ammonia, and can be at the same time used for the color determinations.

In this measurement of the color of surface waters it is well to bear in mind that we are dealing often with colors of considerable intensity, and that it would be out of the question to measure the color in greater depth than a few inches. Now this is a very different matter from measuring the color of waters in two-foot tubes, as is done in the "color meter." This apparatus, now regularly used by the chemists in charge of the examination of the London Water Supply, records the amount of brown and the amount of blue in the water as seen through a depth of two feet. It is obvious that a method of this character could only be employed on waters which would ordinarily be called colorless. A

water having a color of more than 0.3 on the scale which I use is nearly opaque when observed in a depth of two feet.

I have not made out any definite connection between the character or intensity of the odor of a water and the amount of its organic contents. But in the case of the color of the water this connection is very close, and we can predict in a general way from the color what the analyses of the water will show.

The relation between the intensity of color and the amount of albuminoid ammonia may be seen in the following analyses of river, brook, and lake waters.

Source.	Color.	Alb. Ammonia Parts in 100,000.
Basset Brook Reservoir, South Adams	0	.0040 to .0064
Dry Brook Reservoir, South Adams	.2 to .4	.0100 to .0165
Sudbury and Cochituate Supply, Parker Hill Reservoir,	.2 to .5	.0167 to .0248
Merrimack River at Lowell	.2 to .75	.0147 to .0209
Taunton River, Dunbar's Bridge	1.1 to 1.8	.0251 to .0357
New Bedford Supply	1.2 to 2.2	.0242 to .0360

It is not to be expected that the same color, in waters of different origin, will be accompanied by the same amount of albuminoid ammonia; neither is a close correspondence to be expected in water from the same source at different periods of the year. Further, the subject is complicated by the amount of suspended matter or sediment in the water, which contributes largely to the albuminoid ammonia, and does not contribute to the color, which is due to organic matter in *solution*.

A good instance in point is the water of Jamaica Pond which, with no color, gave in June, .0618, and in October .0263 albuminoid ammonia. In both these cases there was considerable light white suspended matter, and notably more in June than in October. If this vegetable matter had been filtered out the result would doubtless have been that the albuminoid ammonia would have been low, as is generally the case in colorless waters.

An experiment made on some fresh autumn leaves furnishes interesting data on the correspondence of color and albuminoid ammonia. Leaves, freshly gathered, were treated with pure water until it had acquired a color of 0.8. This on examination was found to have .0494

parts of albuminoid ammonia. A subsequent infusion of these leaves, having the same color, namely 0.8, contained only .0178 parts. Old leaves which had been repeatedly treated with water and were more or less disintegrated gave, with a color, of 0.9 only .0072 albuminoid ammonia. This indicates a ready solubility of the nitrogenous matter of fresh leaves. It was noted that the color of the first infusion of the leaves was rather more yellow than that obtained from older leaves.

The influence of different kinds of leaves is shown in the following experiments. A fragment of an elm leaf, about the size of a 5-cent piece and weighing 9 milligrams (.015 of a grain), was put into absolutely pure water and the free and albuminoid ammonia which it was capable of developing determined. The results were 0.000008 gram free ammonia and 0.00036 albuminoid ammonia. If this amount of ammonia had been obtained from a liter of water we would express it in parts per 100,000 as .0008 free ammonia and .0036 albuminoid ammonia. A complete elm leaf of average size would give to a liter of water 20 times this amount of ammonia. A rough calculation based on these figures indicates that one pound of fresh leaves could communicate to 2,000 gallons of water an amount of albuminoid ammonia equal to .0150 parts in 100,000. A further experiment with a maple leaf gave somewhat less free and albuminoid ammonia, and an oak leaf decidedly less albuminoid ammonia in comparison with the elm, in the proportion of 36 in the case of the elm to 25 in the case of the oak. Maple leaves color water more intensely than either oak or elm. In the bottle before you are 3 leaves, a maple, an elm, an oak leaf, each weighing about 170 milligrams (2.6 grains), which were put into 4 liters of distilled water on December 7th. The color to-day, December 14th, is 0.3.

Peat is largely vegetable and mineral matter with more or less of the products of animal life. It gives to water a decidedly brown tint and also considerable nitrogenous matter which appears in analyses as albuminoid ammonia. From old peat the amount of albuminoid ammonia is very much less for the same depth of color than in the case of leaves. This might be expected from what has already been said, that the infusion of fresh leaves gives much more albuminoid ammonia than that made with old leaves. In peat solution there is generally also some free ammonia, perhaps, from the animal matters present.

The relation between color and albuminoid ammonia is, moreover, strikingly shown by the direct experiment of removing the color. This we can readily do by hydrate of alumina. This substance has a great affinity for coloring matters, and is used in the arts to precipitate various colors from solutions in making lakes. A very small quantity only

is necessary for this purpose. Thus if we agitate say a quart of dark-colored water with an amount of hydrate of alumina which would compound to 6 grains of alum, the alumina will settle to the bottom with all the coloring matter and leave the water perfectly colorless. This is much more than is absolutely necessary for the purpose, but in laboratory experiments an excess is desirable. If now we determine the amount of albuminoid ammonia both in the original and clarified waters, we learn how much has been removed with the color.

Following are a few examples of determinations of this character. A water with a color of 1.2, contained .0296 parts per 100,000 of albuminoid ammonia. After decolorization with alumina it had only .0048 parts, a removal of 84 per cent of the total amount. Water from the same source at another time with a color of 0.9 and albuminoid ammonia .0256 parts, had 88 per cent removed by treating with alumina.

The effect of this treatment with hydrate of alumina on artificially prepared solutions of leaves and peat (seen in the bottles before you) is shown in the following determinations.

	Color.	Albuminoid ammonia.	Albuminoid ammonia after decolorizing with alumina.	Per cent of albuminoid ammonia removed.
Peat solution	2.	.0516	.0136	73.7
Fresh leaf solution	0.8	.0494	.0100	79.8
Second extract of same leaves . . .	0.8	.0174	.0036	79.3
Solution of old leaves which had been repeatedly extracted with water . . .	0.9	.0072	.0018	75.0

This residual albuminoid ammonia represents, I think, the soluble nitrogenous matters which were not associated with color; but more investigation is needed before I can speak definitely on this point.

In this connection an experiment on a solution of animal matters without any of vegetable origin, may be mentioned. This solution, which was colorless, gave 0.3240 albuminoid ammonia, and after treating with alumina the same amount was obtained, showing that the alumina was without effect on this colorless, animal nitrogenous matter. Experiments on sewage treated with alumina show generally a small decrease of nitrogenous matter. In two instances in which the sewage had been previously filtered through paper, alumina removed only 33 and 38 per cent. Another instance showing the combined influence of color and

suspended matter is interesting. A water containing a considerable quantity of suspended greenish vegetable matter, with color, when filtered, of 0.1, gave 0.1920 albuminoid ammonia; after treatment with alumina it gave .0072 parts, a decrease of 96 per cent. But filtering through paper only, which removed the greenish suspended matter, reduced the albuminoid ammonia to .0252, a decrease of 87 per cent, irrespective of the soluble coloring matters. Thus the effect of the alumina alone may be calculated to be the removal of 71 per cent of the nitrogenous matter left in solution after filtering through paper. The action of alumina, it must be remembered, is not only to remove the coloring matter, but it carries down with it also all the suspended matter.

Most surface waters contain more or less suspended matter, and the lighter portions are carried through the supply pipes to the consumer. When the water is analyzed, it may make a very considerable difference in the determination of the albuminoid ammonia whether or not this suspended matter is previously removed by filtration or by settling. This suspended matter is often light vegetable substance, and contributes materially to the amount of albuminoid ammonia. In some seasons of the year this vegetable suspended matter may be more abundant than in others, and the turbidity after the heavy rains will likewise have an influence on the composition of the water. In analyzing a water ought this suspended matter to be included, or ought it be filtered out, so that the analysis may show only what is in *solution* in the water? It seems to me that the proper answer to this question is, that the suspended matter should be included when it is light and settles with difficulty, for in such case it is actually consumed with the water. Whether the effect of suspended organic matter is the same as dissolved organic matter it is hard to say, but I think the chemist should include it in his analysis, when the consumer includes it in the water he drinks.

It is not the purpose of this paper to deal with the subject of filtration of surface waters, but it may be said, in passing, that the ordinary household filter can give us water free from sediment, and where charcoal is used the water may be at the same time more or less decolorized. The action of alumina in removing color is probably very different from charcoal; it is certainly very much more effective in removing the color from water. Ordinary clay is also efficient in this respect. In fact, there are very few soils which will not, even in thin layers, remove the brown color from waters. Pure quartz sand is almost without effect, as is also pure amorphous silica, but the admixture of a small amount of fine clayey or loamy earth with the silica gives it the power to remove

color, and with the color goes the albuminoid ammonia which was associated with it.

The ideal drinking water, *as far as appearance goes*, is certainly the clear, colorless, cool, sparkling water which flows from the hillside, or is drawn from the deep well. And yet many of the brown waters, unattractive as they may be in appearance, are characterized by their stability and freedom from animal contamination. The chemical evidence of the putrefactive change of nitrogenous organic matter is the appearance of free ammonia in the water. Notwithstanding the fact that the brown waters all contain considerable nitrogenous vegetable matter in solution, they seldom, when uncontaminated with animal refuse, show much free ammonia. Even when kept in bottles, more or less exposed to the air, for a month or more they show but little tendency to change.

	Color.	Ammonia. Free.	Ammonia. Album'd	Ammonia. Free.	Ammonia. Album'd	Ammonia. Free.	Ammonia. Album'd
Taunton River	2.0	June 22. .0032	.0333	June 30. .0026	.0350		
" "	1.8	Aug. 12. .0042	.0357	Aug. 24. .0038	.0368	Sept. 2. .0008	.0336
Neponset River	1.6	Aug. 10. .0062	.0509	Aug. 24. .0012	.0348	Sept. 2. .0012	.0392
Athol, Brook Water . .	1.1	Aug. 12. .0011	.0278	Aug. 24. .0006	.0258	Aug. 31. .0032	.0288
Cochituate Supply-Tap .	0.4	Aug. 2. .0000	.0172	Aug. 14. .0005	.0164	Aug. 24. .0000	.0142
Artificially prepared leaf solution	2.0	Oct. 21. .0018	.0274	Dec. 8. .0014	.0224		
Old peat solution . . .	2.4	Nov. 8. .0038	.0086	Dec. 8. .0092	.0070		

A few examples will illustrate this. A number of dark-colored waters were preserved in glass-stopped bottles, with occasional exposure to the air, and at intervals of a few weeks they were examined for free and albuminoid ammonia.

Whatever may be said against Boston's Sudbury and Cochituate supply as regards odor and color, it is certainly to be commended for its

In the last two numbers of the series, the greater permanence of pure leaf solution over the peat is noticeable, and also the greater proportion of albuminoid ammonia in the leaf solution in proportion to the color.

stability and freedom from change in the condition in which it flows from the tap of the consumer.

I do not intend to convey the idea that because a water is brown and peaty that it is, therefore, constant in composition. Instances are numerous enough where brown waters which have been subjected to successive examinations at intervals of a few weeks, have shown a large development of free ammonia. This may be in some cases directly referred to sewage or manufacturing refuse. It is also not impossible that some highly nitrogenous vegetable growths are susceptible of putrefactive change with development of free ammonia. This is a matter for the combined investigation of the botanist and chemist. Still, it may be accepted as a fact well established, that a water may have a decidedly high color and high albuminoid ammonia of purely vegetable origin, which is of great permanence, that is to say, which has little or no inclination to undergo putrefactive change.

In comparing waters with regard to contents of albuminoid ammonia, it is always necessary to take into consideration this question of color. If, for instance, a water of color of 1.0 has .0250 parts of albuminoid ammonia, it need not excite suspicion. If, however, a colorless water has .0250 or more parts of albuminoid ammonia, it is sufficient cause for rejection of the water if no sufficient explanation is at hand.

He would be a rash man who would, under any circumstances, try to establish a rigid standard of purity for drinking water based on chemical analysis alone; but in any case it is obviously impossible to have the same standard for both colored surface waters and colorless filtered and ground waters. The more we study water by chemical processes, the more I am convinced of the real service that chemistry can render the troublesome question of the availability of a water for drinking purposes. But the water must be studied in the field as well as in the laboratory, and the results of both investigations must accord if the conclusions are to have any value.

In conclusion, I wish to acknowledge my indebtedness to Mrs. R. H. Richards, the Instructor in Sanitary Chemistry in the Massachusetts Institute of Technology, and my associate in the water work of the State Board of Health, for much valuable assistance in the preparation of this paper.

A STUDY OF CERTAIN ERRORS IN THE CONSTANT SHUNT METHOD.

BY WILLIAM L. PUFFER, S.B.

Read at a meeting of the American Academy of Arts and Sciences, January 11, 1888.

A VERY neat and valuable application of Ohm's Law is that usually called the shunt method for the determination of current. The method is described in the Munich, Vienna, and Philadelphia Reports on dynamo tests as well as in the *Electrician and Electrical Engineer* for January, 1885.

The principle is this: if a conductor of constant unknown resistance be placed in a circuit, and currents of different strength passed through it, there will be a difference of potential at the terminals of the conductor proportional to the currents flowing; and if this conductor be placed as a shunt upon a reflecting galvanometer whose resistance is high as compared to the conductor, and whose deflections are proportional to currents producing them, then the deflections will be proportional; first, to the currents in the galvanometer circuit; second, to the potential difference in the conductor; and third, to the currents in the conductor.

In order to extend the range of the apparatus, the galvanometer deflection can be kept the same by changing the total resistance in its circuit; then this total resistance is also proportional to the potential difference in the conductor. In order to save time, the galvanometer deflection may be nearly the same, and the product of the deflection and corresponding total resistance taken; these products will then be a measure of the corresponding currents in the conductor. If a known current be passed through this conductor or shunt, and the galvanometer deflection and total resistance of the galvanometer circuit multiplied, and the product divided by the known current expressed in ampères, we get the constant of the apparatus for ampères. To find value in ampères of an unknown current, we have only to note the deflection and total resistance in galvanometer circuit, multiply them, and divide by the constant. Or we could divide the known current by the product of resistance and deflection, and get a constant by which to multiply the resistance and deflection obtained with the unknown currents.

The range of the method is very great, and is, perhaps, limited only by

the difficulty of making a suitable shunt of such a cross section as to be free from injurious heating by the currents used.

Wishing to employ this method in the Rogers Laboratory of Physics in a slightly different way, requiring that the shunt resistance be known, I made some experiments to determine the resistance of a German silver rod 3 feet long and 0.6 inch in diameter, with the intention of using it as a constant shunt of *known* resistance for currents from about 1 to 60 ampères. An inch from each end a small wire of German silver was silver-soldered in a hole drilled nearly through the rod, and the lead wires running to a low resistance galvanometer were connected by screw-clamps. On the ends of the shunt were soldered brass screw connection for insertion of the main wires.

A standard ohm was placed in circuit with the shunt by means of mercury cups and the resistance of the shunt found by comparison of the potential at its terminals with that at the terminals of the ohm, using a Hartmann dead-beat galvanometer and resistance box as usual with the shunt method.

The results were very unsatisfactory, although care had been taken to prevent, as far as possible, any error due to change in temperature, by placing both the shunt and the standard ohm in a water bath, and noting the temperature both before and after a set of readings.

As the observations were taken in a short time, and the resistances measured immediately afterward, it is not probable that there could have been any noticeable change during the experiment.

With the shunt in water, the results checked within about 0.3 per cent, the highest being 0.00 085 39, and the lowest 0.00 085 10 ohm. When the shunt was in melting ice the results were more variable, and in air very bad. A careful test of the wires and connection showed that when there was no battery in circuit, there was a variable electro-motive force in both the galvanometer circuit, and in the shunt itself, sufficiently great to account for the errors in previous work.

The error in the galvanometer circuit was avoided by greater care in manipulation and the use of a mercury commutator; but the shunt proved so troublesome that a study of the nature of the small, disturbing electro-motive force observed seemed desirable.

As this error, which I attributed to thermal action, was entirely negligible in the standard ohm because of the comparatively high difference of potential produced by the calibrating current, I thought that a German silver shunt, capable of carrying 5 to 10 ampères, having a resistance of from 0.1 to 0.2 ohm, might be compared with the ohm, and then with the shunt, without any appreciable error from heating or thermal action.

The following is a brief description of the shunts made, and the arrangements for taking observations and avoiding errors: —

The large German silver shunt has already been described. The standard German silver shunt was made of a 50-foot length of wire of $\frac{1}{4}$ inch diameter, drawn to order and of the quality known as "18 per cent." A short length of No. 14 German silver wire was looped around this shunt near each end and silver-soldered to it, using borax as a flux, and similarly a set of copper wires as well, thus giving me virtually two shunts of the same resistance and material, differing only in the metal wires used for the potential leads. The shunt wire was doubled and bent back and forth through porcelain insulators fastened to a piece of board. Also a copper shunt was made of two pieces of No. 00 wire, each eleven feet long; these were connected by being soft-soldered into a brass block, using resin as a flux, and then coiled in the same directions, to avoid magnetic disturbance, and suspended from ebonite supports in a stone jar. At three places on this shunt — near each end and in the middle near the brass block — were soldered a set of four wires. Each set of four contained a German silver and a copper wire, silvered-soldered with borax, and a similar pair soft-soldered with resin. This was equivalent to twelve simple copper shunts, with different leading wires and solders.

Each of these three shunts was placed in a tank of water provided with a thermometer. The potential wires were carried to mercury cups and commutators on a table thirty feet away, where the resistance boxes were placed.

The galvanometer was a double coil Hartmann, with bell magnet and copper damping-block; the deflections were read by a telescope and scale at a distance of 3.68 metres.

The galvanometer wires were soldered to amalgamated brass rods held in a piece of ebonite provided with a long handle, used in changing the connection from one set of wires to another.

In order to avoid temperature correction, the shunts were placed in water and carefully watched until it was evident there was no perceptible heating of the water or wires by the current. A loop of the galvanometer leads was always connected to a Wheatstone Bridge used to measure the resistance in circuit. There was never any change large enough to cause any trouble, as the measurements were all taken in a short time, and the rise of temperature was very slow.

The deflections were always brought to about 10 double centimeters each side of the middle of the scale, and were written 1000, calling the tenth of smallest division unity. Within the limits of the scale the proportionality of the deflections was nearly perfect, and quite so within the

limits of working. The error due to change in length of the suspending fibre was studied, and found to be negligible only when the precaution was taken to compare a mark on the mirror with a mark on the metal frame of the instrument, and adjust the height of the mirror to 0.1 or 0.2 millimetre. The torsion of the fibre was negligible in the range of deflections used.

The galvanometer and its connecting wires had a resistance of 4.7 ohms, and was used as a voltmeter for measuring the thermal electro-motive forces with an accuracy of about 5 per cent. The factor 0.00 000 040 was used to multiply the deflections by in order to obtain the thermal action in volts, when no resistance other than the galvanometer and connecting wires was in circuit.

It was assumed that these shunts would be calibrated with a current of 1 ampère, and that an accuracy of 1 part in 1000 was desirable. The table gives the resistance of the shunts, and also the volts corresponding to an error of 0.1 per cent of the difference of potential caused by a calibrating current of 1 ampère. These small electro-motive forces are represented by 2 units of deflection of the voltmeter in the case of the copper and the large German silver shunts, and 2000 with the standard shunt.

	Resistance in ohms.	0.1% P. D., due to an ampère.
Large German silver shunt	0.00 085	0.00 000 085
Standard German silver shunt	0.16	0.00 016
Half of copper shunt	0.00 070	0.00 000 070

The large G. S. shunt in air often showed from 1 to 3 units deflection, sometimes in one direction and sometimes in the other; but when placed in water this error was reduced to a much smaller amount, and seldom could be detected. At one time there seemed to be a variable deflection, which was traced to the contacts in the screw connection used to join the galvanometer leads to the shunt wires; this was easily removed by bending the wires until the clamps were under water. After this I could never detect any deflection caused by thermal action in this shunt, although owing to the low resistance of the shunt an error of 0.05 per cent would cause so small a deflection that it might pass unnoticed.

The copper shunt, with its different terminals, proved very interesting, and exhibited a great variety of thermal action which would, in many cases, be too large to be neglected if the shunt was to be used for comparison of currents.

The largest deflections were always found with the German silver wires, and the least with copper wires with soft-soldered connection. The deflections were seldom twice alike even with the same wires, ranging from 0.0 to 20., being positive at one time and negative at others. The difference between the silver solder and the soft solder was not particularly marked, but seemed to be in favor of the soft solder, both with the copper and German silver leads. These deflections were always smaller and more regular when the shunt was in water than in air. It often happened that the copper soft-soldered leads gave no indications of thermal action, and I never saw any indication of trouble from the double-soldered connection in the middle of the shunt.

This shunt was made to correspond approximately to some of the shunts described in articles on the shunt method of determining currents both in regard to size and length of wire and method of connecting the lead wires.

The thermal action in the standard G. S. shunt was very much greater than in any part or combination of the other shunts, being larger when the copper leads were used by about 7 per cent; still, even these large thermal E. M. F.'s were quite small when compared to that produced by the calibrating current, and could have been safely neglected if an accuracy of 0.1 per cent was required. I thought I could now compare this shunt with the standard ohm easily enough; and then with the other shunts by using a current of several ampères, to get so great a difference of potential that the thermal effects would be drowned. I changed the storage battery letting the current pass through all three shunts, and after a few hours I broke the circuit, and tested the shunts to see whether the current had perceptibly heated them, although a sensitive thermometer showed no change. The copper and large G. S. shunts seemed about as usual, but the standard gave me a deflection of 2000, which rapidly diminished. This was far too small to be of any effect with this particular shunt, but it was very suggestive. Examination of the shunt showed a slight blackening at the positive end and a few bubbles of gas, probably due to slight decomposition of water, as the difference of potential had been about 1.8 volts. A reversal of the current caused the blackening to appear at the other end of the shunt, and a slight lessening of the discoloration produced by the previous current.

A current of 22 ampères in all three shunts produced 3.5 volts in the standard, and in breaking 0.00 06 volt at the end of half a minute, which fell to 0.00 000 2 at the end of five minutes. The deflection was in the same direction as when the current was passing, and was reversed by reversing the current. The other shunts gave no such effects even with 60 ampères, so work was chiefly on this shunt. A current of 45 ampères caused an effect which sent the spot off the scale for over a minute.

Curves were plotted, showing the diminution of the thermal effect at equal intervals of time after stopping the main current, which show that while the current is passing, the apparent resistance of the shunt is greatly increased by this action. It appears as if this counter electro-motive force increased with the current, although not quite in the same proportion.

At this point my experiments had to be postponed, so all apparatus was put aside for a number of months, and then set up in exactly the same manner and position, with the exception that I only used the standard German silver shunt, to which I added three new sets of terminals,— two of German silver and one of copper, all soft soldered, using acid for a flux.

Experiments were made to find what caused the variable deflection from this shunt after a current had been passing, and to see if there was any noticeable difference in the materials used in the potential leads and solderings.

I designated the different sets of leads in the following manner :—

Leads	No.	1	were of	German silver,	soft-soldered.
"	"	2	"	Copper,	"
"	"	3	"	German silver,	"
"	"	4	"	Copper,	silver "
"	"	5	"	German silver,	" "

When the shunt was in air, the effects — due to thermo-electric action arising from the slight differences in temperature in shunt itself previous to the passage of a current,—were found to be of such a magnitude as to be negligible in a shunt of so high resistance as this one, although far too great to be permissible in a shunt of a resistance corresponding to those generally used. These thermal electro-motive forces varied both in sign and amount from zero to 0.00 000 12 volt, and having as an extreme variation about 0.00 000 24 volts. In this respect the German-silver leads were anywhere from two to five or more times as bad as the copper, and the too soft-soldered ones seemed to be best, although not enough so to make any marked difference in the readings, which were very small at most. The difference between the copper leads was not appreciable.

With the shunt in air I allowed various known currents to flow for five minutes, and then took several series of readings every quarter or half minute for about five minutes or longer, if necessary, to see what effect was produced in the shunt by the passage of the current. When the currents were only two or three ampères there was no effect produced large enough to notice; and as I could readily detect an electro-motive force greater than 0.00 000 04 volt the action, if any, must have been very small. With currents that produced a perceptible warming of the wire, I

found a great variety of effects, differing even in the same set of leads at different times.

Curves were plotted, showing the effect produced by a current of 24.2 ampères in the shunt for five minutes. The sets of wires called No. 1 and No. 3 were made of the same piece of wire, and soldered at the same time with the same solder; and yet they vary in a very peculiar way, for which I have no explanation except that the composition of the German silver shunt has been acted upon by the solder used, and that in the short length (about two inches near each end), where the soldered joints are, the metal is not homogeneous.

The greatest deflection shows the electro-motive force to have been 0.00 002 volt. Both sets of copper wires act in a similar manner, and give curves which rise quickly during the first half minute, and then gradually drop. Terminals No. 5 give a curve which begins high and falls sharply, and recovers slightly only to fall again. The curves of No. 3 fall rapidly at first, then rise in a regular and very marked manner, after which a fall takes place. Terminals No. 1 do not give especially marked curves unless it be on account of the much smaller deflections than any of the other wires.

I next placed the shunt in water, and examined it the next morning before passing any current through it, and found a large deflection of 105 units, corresponding to 0.00 004 2 volt. There was a slight difference between the various leads, generally about 5 per cent, but all deflections were in the same direction. I was careful to see that all parts of the shunt were under water, and that the soldered junctions were at nearly the same depth, but still the deflections remained. A current of 25 ampères was sent through the shunt to see if there would be a similar action to that when the shunt was in air, but upon connecting the galvanometer the deflection was entirely off the scale for five minutes, and lasted for an hour. I found that a current of less than an ampère in the shunt, but in the opposite direction, would reverse for a while the remains of the effect due to the 25 ampères. There was no apparent difference in the leads, and as the deflections were reversible by reversing the current, and always opposite to those produced directly by the current, I concluded that there was an electrolitic action caused by the current. The positive end of the shunt always turned black, and the negative end tended to become white. I found that by carefully timing duration and direction of currents, I could get a right deflection which would diminish and a left one begin, which would in turn give way to another right deflection, but I was not able to get four changes. With the soldered ends entirely out of water the actions were exactly the same; but the moment the *whole* shunt

was out of water all action ceased, and the deflection became very small: even ten inches of submerged wire gave the deflection, though to a lesser degree, as did also a wet rag wrapped around the wire for a short length.

A current of less than an ampère would produce less than 0.2 volt at the terminals, yet I could get these effects by it, so that simple decomposition of the water was not the cause of the trouble, which it seems to me must be attributed to a "polarization" effect. Having found the cause of the strange deflections when the shunt was in water, I did not continue the experiments any longer. The reason the large German-silver shunt did not show such trouble is, probably, that it had been carefully shellaced when made, and was protected from the oxidizing action.

In the light of these experiments, it seemed desirable to plan a shunt and galvanometer for use in comparing currents ranging from 1 to 1000 ampères, which would not be affected by either thermal electro-motive forces in its circuit or in the shunt itself. These data were assumed, and the galvanometer calculated.

Calibrating current to be 1 ampère.
Largest current to be 1000 ampères.
Resistance of shunt to be 0.001 ohm.
E. M. F. at terminals when calibrating 0.001 volt.
Largest observed thermal E. M. F. 0.00 000 8 volt.
Average observed thermal E. M. F. about 0.00 000 08 volt.
Galvanometer current when calibrating to be less than 0.001 ampère.
Galvanometer coils to be 25 ohms of German silver wire.
Deflection to be 10 c.m. at 1.5 meters, or about 2°.
Earth's field alone to be used.
Required dimensions of galvanometer.

The field due to the coils must be 0.006 in order to produce a deflection of 2° where H is 0.1717. The current producing this field would be 0.00 000 4 absolute unit; 25 ohms of No. 18 B. & S. German silver wire would be a length of 8,440 c.m.

$$\text{Then radius of coil} = \sqrt{\frac{8{,}440 \times 0.00\,000\,4}{0.006}} = 2.37 \text{ c.m.}$$

$$\text{Average length of a turn} = 2\pi r = 14.9 \text{ c.m.}$$

$$\text{Number of turns} = \frac{l}{14.9} = 566 \text{ or } 283 \text{ per spool.}$$

15 × 19 turns give a coil section 0.604 × 0.766 inch.

The galvanometer was made of a single copper casting, with two channels for the coils, 0.2 inch apart. Each channel was 0.77 inch deep, 0.61 inch wide, and had an inside diameter of an inch. If the galvanometer is

much lower than 25. ohms, the variable plug resistance of an ordinary bridge will cause an error too great to be safely neglected when only the galvanometer, leads, and plugs are in circuit. The reasons for the other numerical figures are almost self-evident.

The shunt itself I would make of thin sheet German silver, with either copper or German silver end blocks, as was most convenient, but preferring copper. The lead wires to the galvanometer would be of copper, either soft or silver-soldered to the end blocks, and should go to a commutator very near the shunt itself, and the galvanometer circuit so arranged as to be easily disconnected from the shunt and placed in a mercury cup to close the circuit for the resistance measurement. I would prefer to measure the total resistance by a standard bridge always connected and kept at a constant temperature.

This kind of a shunt could easily be made so that there would be very little heating, and if shellaced, or protected from oxidation in any other manner, could be used in water, although some kind oil would probably be better.

There should be suitable mercury cups arranged so that the current could be easily and quickly reversed in the shunt, or the shunt entirely disconnected from the circuit.

Rogers Labratory of Physics, January, 1888.

A BIOLOGICAL EXAMINATION OF THE WATER SUPPLY OF NEWTON, MASS.

BY W. T. SEDGWICK, PH.D. AND S. R. BARTLETT, S.B.

Read before the Society of Arts, Jan. 12, 1888.

THE city of Newton gets its water from a filter-basin 1,575 feet long, running alongside the Charles River in the town of Needham. The water in the filter-basin is pumped by engines in a pumping-station near by, to a reservoir some four miles distant on Waban Hill, from which it flows by gravity to all parts of the city. In the spring of 1887 the authors made in the Biological Laboratory of the Institute of Technology a quantitative bacteriological examination of the water from the Charles River, the filter-basin, the reservoir on Waban Hill, and the tap in the city of Newton, estimating carefully the number of bacteria and moulds in equal samples of water taken from the different localities on the same successive days. At the same time

Mrs. Richards and Mr. Bartlett carried on a chemical examination of similar samples in the Institute Laboratory of Sanitary Chemistry. In the course of the investigations 145 biological and 117 chemical analyses were made; and all the work was done between April 1st and May 15th.

The method employed in the biological examinations was the well-known gelatine plate-culture method of Koch. The usual accessory apparatus was employed, and need not be described. The principle underlying the method is this: By mixing a known volume of the water under examination with a much larger volume of so-called "sterilized nutrient gelatine," the germs in the water are first *separated* somewhat widely from each other in the melted gelatine; and afterward, when the gelatine has been poured out on a cool plate carefully leveled, are *kept* separate and isolated by the stiffened mass. They are thus held securely apart, but may still easily grow and multiply in the nutrient mass, enriched as it is by meat extract, peptone, etc. At first the gelatine appears perfectly clear and pure; but after a day or two, comparatively opaque whitish or yellowish dots or islands may be detected, due to the rapid, though localized, increase of the germs. Each of these dots, if caused by bacteria, is called a "colony," and is taken to represent one "germ" in the original water, provided the gelatine used was properly sterilized, *i. e.*, freed from all living germs. Moulds have an equally characteristic, though different appearance, and thus both may be recognized after a time, and the total number of living "germs" in the original sample readily and accurately estimated.

Some of the more important results are indicated in the following tables: —

NUMBER OF BACTERIA PER CUBIC CENTIMETRE OF WATER.

1887.	Charles River.	Filter Basin.	Waban Hill Reservoir.	A Tap in Newton.
April 1.	315	15	. . . . .	. . . . .
April 6.	267	80	Apr. 11, 18	8
April 18.	220	48	48	6
April 27.	175	40	20	0
May 1.	200	15	10	4
May 9.	150	64	18	April 29, 12
Averages . .	221	43	23	6

The water brought in for examination was collected and transported with great care in small glass-stoppered bottles holding about 60 c.c. These were carefully cleaned and inclosed in tin canisters made to fit them rather tightly, and all were thoroughly sterilized at 160° C. in the hot-air sterilizer. The tin covering prevented any accumulation of dust around the stopper, and allowed, without injury, considerable knocking about in transportation. In getting the sample of water desired the bottle was taken from its case, rinsed in the water to be collected, held well under, and filled by lifting the stopper. It was then returned to its tin case, and thus conveyed to the laboratory, where the culture was made, usually within three hours from the time of collection.

BACTERIOLOGICAL COMPARISON OF THE TAP WATER OF NEWTON AND BOSTON (BACK BAY) DURING ONE WEEK.

DATE.	COLONIES PER C.C., NEWTON.		COLONIES PER C.C., BOSTON.	
	A	B	A	B
May 6.	0	4	48	60
" 7.	6	12	30	44
" 8.	Sunday.	Sunday.	Sunday.	Sunday.
" 9.	8	14	40	52
" 10.	0	4	24	60
" 11.	2	4	28	32
" 12.	0	8	25	35
" 13.	12	15	55	65
Averages . .	6		43	

Average number of bacteria per c.c. found in the water from

Newton (tap)	6
Boston (tap on the Back Bay)	43
Mystic (tap in Charlestown)	204
Spot Pond (pond)	38
Spot Pond (tap in Medford)	10
Jamaica Plain (Boston High Service)	52

The first table shows a considerable and constant difference in the abundance of living bacteria in the several waters examined, and indicates a progressive purity in this respect as the water nears the point of consumption. The largest difference between successive samples is that between the river water and that in the filter-basin, and this is easily explained by a consideration of the conditions prevailing in each. The river is an ordinary stream, draining a rather thickly inhabited country, and hence is more or less polluted. The filter-basin on the contrary, although dug parallel to the river and near it, probably gets from it little or no water. This comes instead from the other direction, owing to the slope of the adjacent country; and especially from eight artesian wells driven in its bottom to a depth of thirty feet, where they penetrate a quicksand and a gravel overlying bed-rock inclined toward the river. Thus it comes about that the water in the filter-basin is sometimes higher than that in the river, and always far more constant in temperature; and thus, too, it happens that the water of the river contained 221 germs per cubic centimetre in April and May, 1887, while that in the filter-basin showed only 43. The filter-basin, even to the naked eye, was much cleaner and purer than the river, although it contained a very considerable amount of filamentous algæ,— principally Zygnema. It is less easy to explain the progressive decrease of bacteria from the filter-basin to the tap, but it is perhaps not unreasonable to suppose that the stock of organic matter, *i. e.*, of food for the germs, in this (principally) artesian water was originally small, and gradually fell short.

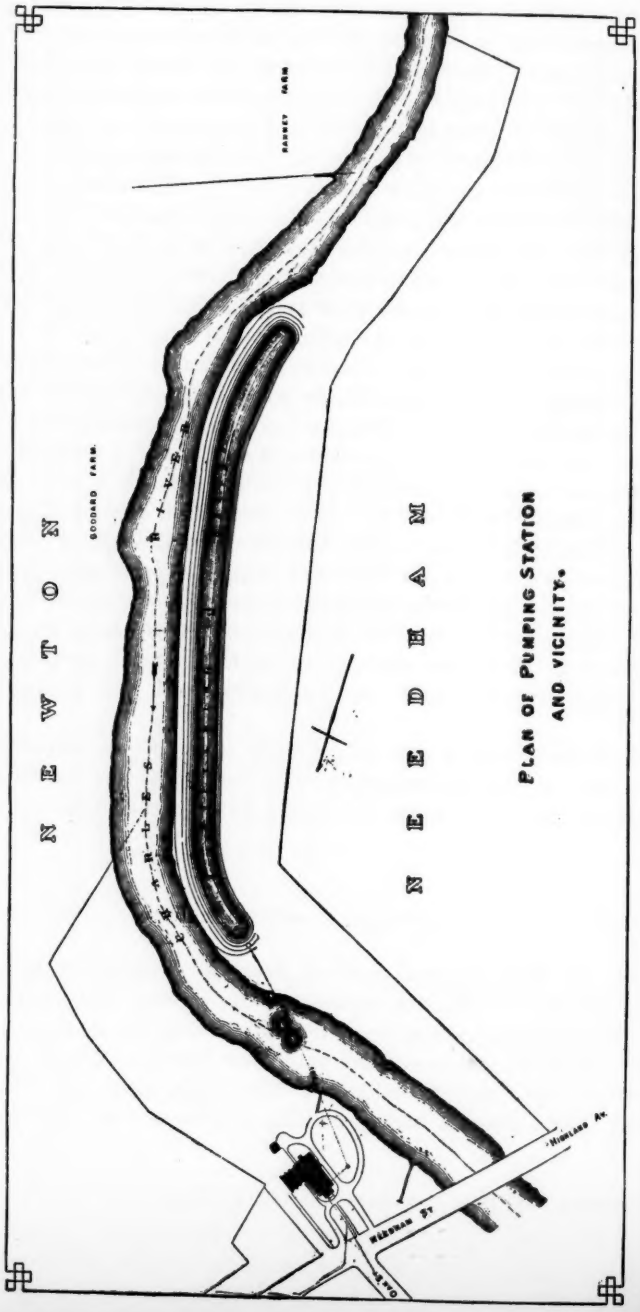
The Newton water supply is generally regarded as very superior, and as will be seen by inspection of the above tables, the biological examination, as far as it goes, abundantly confirms this view.

CHEMICAL EXAMINATION.*

While the biological analyses just described were going on, a considerable number of chemical analyses of the Newton water was carried out in the Institute Laboratory of Sanitary Chemistry.

These chemical analyses of the water were likewise all made between the first of April and the middle of May, 1887,—a season which presumably would give as widely varying results as any season of the year.

* Communicated by Ellen H. Richards and S. R. Bartlett.


NEWTON
NEEDHAM
GODDARD FARM
RAMSEY FARM
HIGHLAND AV.
WARREN ST.
OAK ST.
PLAN OF PUMPING STATION
AND VICINITY.

From the accompanying table it will be seen that the amount of free ammonia was found to be more variable than that of the albuminoid ammonia. It seems to be also definitely established that the analysis of one sample of water, taken on a certain day at a certain season of the year, ordinarily gives no correct indication of the condition of the water the year round, since certain local causes may, for a few days, exercise a marked influence.

It will further be seen that the water was chemically (as well as bacteriologically) better when drawn from the tap than when taken from the reservoir or the filter-basin. This may perhaps be accounted for by assuming that some of the organic matter settles out, and some is decomposed by the bacteria in the reservoir and the pipes.

CHEMICAL ANALYSES OF THE NEWTON WATER SUPPLY.

PARTS PER 100,000.

	Charles River.		Filter-Basin.		Reservoir.		Tap.	
	Free Ammonia.	Albuminoid Ammonia.	Free Ammonia.	Albuminoid Ammonia.	Free Ammonia.	Albuminoid Ammonia.	Free Ammonia.	Albuminoid Ammonia.
April 1	.0070	.0250	.0150*	.0078				
" 6	.0030	.0212	.0014	.0088				
" 11					.0018	.0100		
" 18	.0046	.0254	.0038	.0118	.0320†	.0158	.0018	.0056
" 27	.0012	.0264	.0018	.0138	.0038	.0096	.0004	.0080
May 1	.0014	.0264	.0026	.0126	.0030	.0130	.0004	.0050
" 9	.0050	.0194	.0004	.0120	.0016	.0094	.0012	.0063

A determination of the most important mineral constituents was

On April 1st the ice had just begun to break up.

* Possibly due to melted ice, or to the fact that the water under the ice is more nearly stagnant.

† Taken just after a snow-storm. The banks of the reservoir had also been recently dressed with fertilizer.

made, and is given in comparison with a determination of the same substances in the Boston water supply as follows: —

	NEWTON TAP, MAY, 1887. S. R. BARTLETT.	BOSTON TAP, JULY, 1873. E. H. RICHARDS.
Total solid residue	4.28	5.64
Loss on ignition	.17	2.80
Fixed solids	4.11	2.84
Silica, SiO_2	.77	.28
Lime, CaO	.57	.42
Sulphuric Acid, SO_3 . . .	.57	.91
Iron and Aluminum Oxides, $Fe_2O_3+Al_2O_3$	.34	.85
Chlorine, Cl	.20	.34
Magnesium Oxide, MgO . .	.09	.06
Sodium Oxide, Na_2O . . .	.44	.17
Potassium Oxide, K_2O . .		.25

ON THE ACTION OF HEAT ON ISOBUTYLENE.

BY A. A. NOYES, S.M.

BERTHELOT,[1] some years ago, submitting ethylene to the action of heat, identified among the products of that action, benzene, styrene, and naphthalene; and explained the formation of these hydrocarbons by supposing that a successive union of acetylene molecules takes place. As Dr. L. M. Norton and myself pointed out in an article on the Action of Heat on Ethylene published in the *American Chemical Journal* for 1886,[2] this explanation becomes improbable, in the case of our experiment at least, from the fact that almost no acetylene was found among the products. We showed, also, that the butine vinylethylene is formed in large quantities. The identification of this body is of especial interest, as it is probably the intermediate stage in the formation of benzene, thus making the series of compounds

[1] C. R. 66, 625. [2] Vol. VIII., p. 362.

differing by two carbon atoms complete up to naphthalene: C_2H_4, C_4H_6, C_6H_6, C_8H_8, $C_{10}H_8$. It is evident vinylethylene could not be formed by the union of two acetylene molecules.

If this butine is in reality a normal product of the action of heat on ethylene, it ought, also, to be produced in heat reactions which give rise to ethylene at a temperature sufficiently high to admit of its condensation. In order to determine whether or not this is the case, and to give thus additional confirmation of the view that vinylethylene is the first member of the series of condensation products of ethylene, we have studied the action of heat on isobutylene.

The isobutylene used was prepared by the action of sulphuric acid on isobutyl alcohol, by a method exactly similar to that recommended by Erlenmeyer and Bunte[1] for the preparation of ethylene. The method described by Puchot[2] was found not nearly as satisfactory as this for the preparation of large quantities of isobutylene. The gas was purified by passage through a solution of caustic potash, and was then collected over water in large copper gasometers. Before entering the decomposition tube it again passed through caustic potash solution, and was finally dried by calcium chloride. The gas so obtained was shown, by treatment with strong sulphuric acid, to be nearly pure isobutylene. It contained, however, as impurities, small quantities of nitrogen and carbonic oxide.

The gas was passed slowly through a hard glass tube, heated to low redness for a distance of 60 cm. The products of the decomposition then passed through a series of U tubes surrounded by ice-water, in order to condense any liquid; into ammoniacal cuprous chloride solution, to show the presence of triple-bonded hydrocarbons; and into bromine, to absorb other unsaturated hydrocarbons. Samples of the gas unabsorbed by the bromine were collected over water, and submitted to analysis.

The action was very much more rapid than in the case of ethylene. The products consisted of carbon deposited in the decomposition tube, 25 c.c. of a brown liquid condensed in the U tubes, 200 grams of bromides and unabsorbed gases. Only slight traces of a red precipitate were formed in the cuprous solution. Acetylene and other triple-bonded hydrocarbons, therefore, were not produced by the action of heat on isobutylene.

The liquid obtained from the U tubes was submitted to a number of fractionations. It began to boil at 75°,—the thermometer, however,

[1] Ann. Chem. 168, 64.

[2] Ann. chim. phys., 5th series, 28, 508.

quickly rising to 80°. Portions of four grams each were obtained boiling from 75° to 100° and from 100° to 130°. The specific gravities of these two portions were taken, and found to be .869 and .870 respectively, at 18°. These figures agree closely with those of benzene and toluene, and show that fat hydrocarbons, whose specific gravities are much less, were not present in any considerable amount. The lower boiling portion was tested for benzene by the aniline test. A deep purple coloration was obtained, indicating the presence of that substance. The liquid boiling from 130° to 170° should contain the styrene, if this hydrocarbon is formed in the decomposition; but this fraction was not sufficient in quantity to enable me to establish this fact with certainty. The presence of styrene is probable, however, since the fraction in question was found by titration with standard bromine solution to contain some unsaturated hydrocarbon in large amount. The fraction from 170° to 235° became almost entirely solid on cooling. This solid was pressed between filter paper and sublimed. It then showed the odor, appearance and melting point (79°) of naphthalene. Above 235° a thick, dark-colored liquid and a small quantity of another solid were obtained, which were not investigated. A good deal of carbon remained in the distillation flask.

The bromides were first distilled under reduced pressure, in order to free them from tarry impurity. A colorless distillate passed over, and a dark-colored liquid, which became almost entirely solid after standing over night, remained in the flask. After draining off the liquid these crystals were dissolved in alcohol, boiled with bone-black, and twice re-crystallized. They were then pressed between filter-paper, and further purified by sublimation. The bromide so obtained agreed completely in odor, appearance, solubility and sublimation at a low temperature with vinylethylene tetrabromide. Its melting point, which was 114°.5–115°, and which was not raised by further sublimation, also, was the same as that of that bromide. Bromine determinations made in this gave a somewhat too high result,[1] yet they agree much more closely with the symbol $C_4H_6Br_4$ than with any other probable symbol: —

	Found.	Calculated for $C_4H_6Br_4$.
Bromine,	86.58	85.56
	86.80	

[1] It has been noticed before in this laboratory that the bromide prepared by the union of vinylethylene with bromine, even after repeated crystallization from alcohol, in several cases showed too high a per cent of bromine. Armstrong and Miller, also, found for their bromide 85.99 per cent Br. This is, perhaps, due to a partial substitution at the moment of union of the butine with bromine.

The liquid bromides were separated, as far as possible, by repeated fractionation, and then examined. They were found to consist of ethylene, propylene, and isobutylene bromides and bromisobutylene bromide. The results obtained are shown below: —

	Found.			Calculated.	
	Per cent Br.	Spec. grav.		Per cent Br.	Spec. grav.
125°—132°[1]	83.12		$C_2H_4Br_2$	85.11	2.18
132°—135°		2.03			
138°—142°	79.31	1.97	$C_3H_6Br_2$	79.21	1.95
146°—152°	76.86	1.85	$C_4H_8Br_2$	74.07	1.80
215°—225°		2.15	$C_4H_7Br_3$		2.15

The bromisobutylene bromide was formed by the action of the bromine on undecomposed isobutylene.[2]

The unabsorbed gases were found by analysis to consist of methane and hydrogen.

The substances identified as products of the action of heat on isobutylene, therefore, were: hydrogen, carbon, methane, ethylene, propylene, vinylethylene, benzene, toluene, styrene (?) and naphthalene. No acetylene was formed. As had been expected, the formation of ethylene was accompanied not only by that of benzene and naphthalene, but also by that of vinylethylene.

In conclusion I desire to express my great indebtedness to Dr. L. M. Norton for his valuable advice and assistance throughout the course of this investigation.

[1] This portion, when placed in a freezing mixture, became almost entirely solid.

[2] Norton and Williams. Am. Chem. J. IX., 87.

BOOK NOTICES.

FOOD ADULTERATION AND ITS DETECTION.* BY JESSE P. BATTERSHALL.

MANY of the books which have been written upon food adulteration have been the work of philanthropists, written in the interest of reform, and have taken the ground that the public were in hourly danger from the poisonous character of the food materials cooked for the table.

Sensational writing upon the subject has at times been popular, and one religious sect, numerous in portions of the West, lays great stress upon the impossibility of obtaining pure food as a marked sign of the decay which is characteristic of the last age.

Of late, however, the German chemists have written some very valuable scientific treatises on foods and their adulterations, and in English there is the excellent work of Blyth. In the volume before us we find a fairly full *résumé* of the German and English methods of analysis, with some additional data from American authorities.

The numerous plates are a great addition to certain portions of the work, and features of especial value are the bibliography and the compendium of laws at the end.

The methods are given so concisely that an inexperienced chemist would find some difficulty in following them, and in many cases methods which have not received the sanction of workers in general are included without comment. Indeed, it is a fault throughout that no critical discrimination is made, and no distinction between methods in use in other countries which are applicable to cases brought to the American chemist, and those which are quite worthless in this country.

The sections have not an equal value. Those topics with which the author is most familiar are naturally very fully written out, and although containing nothing new, the chapters on milk, butter, and sugar may be especially noted. The chapter on water is, however, not on a par with the rest of the book, and it almost seems as if some very serious typographical errors must have crept in; for it is hardly conceivable that the method given for the determination of free and albuminoid ammonia as described could have ever been in use. Certainly any young chemist who attempted to give an opinion on the character of water by the method given would very soon bring all chemical tests into disrepute.

* E. and F. N. Spon, New York and London, 1887.

The directions are to distill 100 c.c. of the water to be tested, and to receive the distillates into 10 c.c. Nessler tubes, comparing the colors given by standards "prepared by adding .001, .003, .005, up to .01 gram of ammonium chloride, and filling to the mark with pure distilled water," and Nesslerizing as usual.

In the first place, 100 c.c. of the water to be tested is too small a quantity to use. There is so great a chance of error from various causes that a larger quantity should be taken, especially since the action of the permanganate increases in some cases at the end of the distillation, when it is carried nearly to dryness. However, the taking of 100 c.c. is quite allowable in cases of sewage effluents, only it is advisable to dilute before distilling, since the more ammonia the distillate contains the greater liability to loss on account of insufficient condensation.

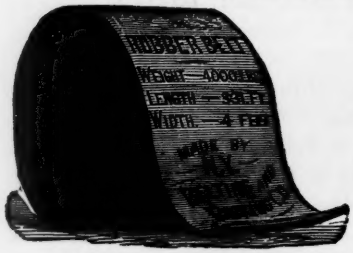
The most surprising statement is in regard to the standards. Directions are given on page 208 for making a standard solution of ammonium chloride such that 1 c.c. would contain .00015 grm., or .00005 grm. NH_3; and yet on page 209 the 10 c.c. tubes are to contain .001 to .01 grm. ammonium chloride. The only conclusion to which the young chemist could come, unless there is a gross typographical error, is that the salt is to be weighed out, since to contain .01 of ammonium chloride there must be taken some 70 c.c. of the solution for a 10 c.c. tube. Again, if the .001 and .01 grm. of NH_4Cl were weighed out and dissolved in 10 c.c. of water, a precipitate would be formed at once on adding the Nessler. The largest amount of NH_3 which can be safely compared in a 10 c.c. tube is not more than .000008, or in NH_4Cl. .000024.

Finally, if it were possible to Nesslerize three distillates of 10 c.c. each, obtained from 100 c.c. of water containing respectively .005, .003, .001 grm. of NH_4Cl, the results would be 3.0000 parts per 100,000 NH_3, — a figure which requires a very rich sewage to reach.

A drinking-water would often be pronounced unfit for use when it contained one hundredth part of that amount of free ammonia.

RUBBER BELTING, PACKING & HOSE.

Oldest and Largest Manufacturers in the United States of



VULCANIZED RUBBER FABRICS

For Mechanical Purposes.

STEAM HOSE

A SPECIALTY.

Rubber Mats, Rubber Matting and Stair Treads.

NEW YORK BELTING & PACKING CO.,

15 Park Row, New York.

HALL RUBBER CO., BOSTON, Agents.

LIDGERWOOD MANUFACT'G CO.,

MANUFACTURERS OF IMPROVED

Hoisting Engines and Boilers

FOR RAILROAD PURPOSES,

Excavating and Pile Driving.

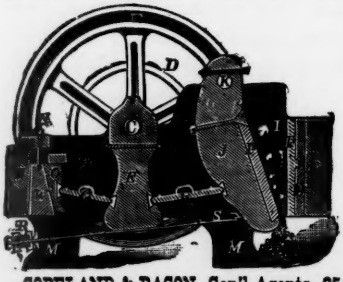
OVER 4000 ENGINES IN USE.

300 STYLES AND SIZES.

J. H. Houghton, Agt., Boston.

WAREHOUSE, 96 LIBERTY ST., N. Y.

IMPROVED ROCK-CRUSHERS.



THE BLAKE STYLE.

For crushing all kinds of hard, brittle substances.

Quartz, Emery & Corundum,

Also TRAP ROCK for

Road Ballast & Concrete.

Over 40 Gold and Silver Medals.

Mr. S. L. MARSDEN, who for the past twenty years has been connected with the manufacture of the "Blake Crusher," New Haven, superintends the construction of this machine.

FARREL FOUNDRY & MACHINE CO.,

ANSONIA, CONN.

COPELAND & BACON, Gen'l Agents, 85 Liberty St., N. Y., 309 Arch St., Philadelphia.